175-0304

technical manual

ELDORADO

ELDORADO ELECTRODATA CORPORATION

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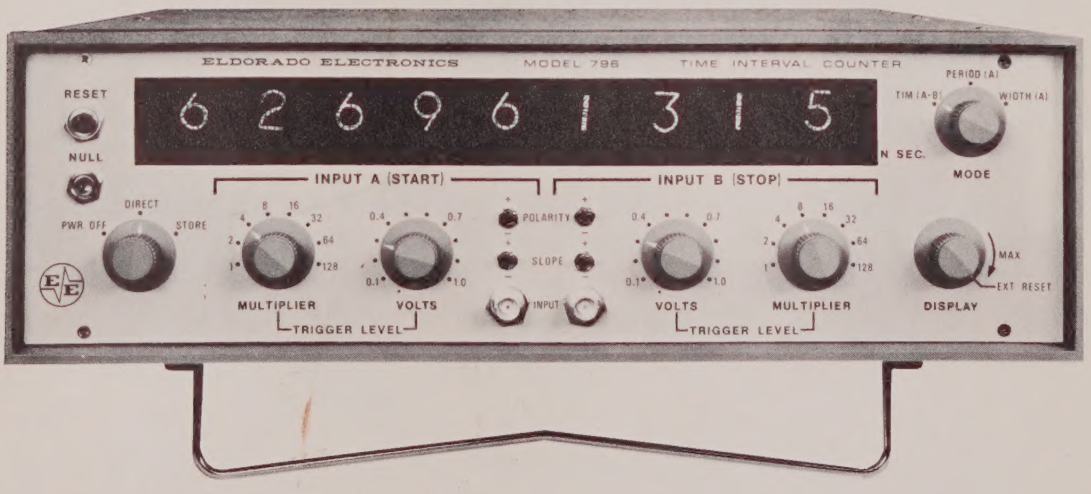
TECHNICAL MANUAL
MODEL 796
TIME INTERVAL COUNTER



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MODEL 796 ADDENDUM - COUNT CHAIN AND DISCRIMINATOR

The Model 796 Time Interval Counter as described in the enclosed manual applies to instruments with serial numbers 205 and below. This addendum describes recent changes made to the accumulator (count chain) and visual display circuits, and the discriminator circuit. This addendum applies to instruments with serial numbers 206 and above.

Basic operation of the instrument is unchanged, and for the most part all the text applies to all instruments. (Only a small part of section 4 which is effected by this addendum does not apply.) Although the specific electronics, circuit design, component parts and physical layout have changed, the overall circuit function within the system remains the same.

The new count chain and visual display circuits are shown on the Count Chain Schematic D-11-06102, the Dual DCU Schematic C-11-06103 and the Overall Block Diagram D-10-06101.

As shown on these schematics the electronics for the DCU's has been modified from solid state discrete circuits to integrated circuit components. Each stage (decade) of the chain is composed of a type MC880 Decade Counter, a type CμL 9959 Buffer Storage Element and a CμL 9960 Decimal Decoder/Driver integrated circuits with 1-2-4-8 BCD Data Output Buffer inverters. Decades 10^0 through 10^7 are mounted on four Dual DCU printed circuit boards plugged into the count chain assembly. The 10^8 decade is a single DCU identical to the dual board except only one DCU is mounted on the board. The Dual DCU are further identified on the PC assembly with the numbers A32-06072 and B32-06072. These boards are selected at the factory and must be positioned within the count chain in the order listed. That is A32-06072 must be used for the 10^0 and 10^1 DCU's and 10^2 and 10^3 DCU's. The boards identified B32-06072 are used in any other position of the chain except obviously the 10^8 slot. Boards stamped with an A may be substituted for boards stamped with a B, however, boards stamped B can not be substituted for boards stamped A. Included with the new schematics showing these circuits are integrated circuits schematic equivalents for the respective integrated circuits used.

The Count Chain Schematic D-11-06102 identifies all Dual DCU's with the number B-32-06072. This is an in-plant drawing number reference and is not to be confused with the A and B stamp appearing on the PC assemblies.

B - 32 - 06072 Drawing Reference

↑ Dwg. Size ↑ Plugin Assembly ↑ Part Number

32-06072	This number normally stamped on boards.
A32-06072	This number stamped on selected boards.
B32-06072	This number stamped on selected boards.

The discriminator circuit has also been modified and is being phased into the instrument over a period of time. Therefore some instruments will have the old discriminator with others having the new. The new discriminator schematic number is D-11-05621. To identify which discriminator is installed in your particular instrument, check the assembly number stamped on the component side of the board. The old discriminators are stamped 32-04814 while the new ones are stamped 32-05637. These boards may also be stamped with a work order number and in some cases the instrument serial number.

Dual DCU (32-06072) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
MC1, 4	Integrated Circuit 9960, Decoder Driver	FAI	CμL9960		2
MC2, 5	Integrated Circuit 9959, Buffer/Storage	FAI	CμL9959		2
MC3, 6	Integrated Circuit 880, Decade Counter	MOT	MC880P		2
Q1-8	Transistor, PNP	MOT	2N4125	T04220	8
R1-4, 9-12	Resistor, Carbon 22K, 1/4W, 5%	AB		R01775	8
R5-8, 13-16	Resistor, Carbon 15K, 1/4W, 5%	AB		R01765	8

NOTE: These boards are selected in test for operation. The 10^0 and 10^1 DCU and 10^2 and 10^3 DCU assembly are coded with the part number A32-06072. The remaining Dual DCU assemblies are coded B32-06072. When ordering complete printed circuit board assembly be sure to identify the board part number completely, i.e., A32-06072 or B32-06072.

Single DCU (32-06093) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
MC1	Integrated Circuit 9960, Decoder Driver	FAI	CμL9960		1
MC2	Integrated Circuit 9959, Buffer/Storage	FAI	CμL9959		1
MC3	Integrated Circuit 880, Decade Counter	MOT	MC880P		1
Q1-4	Transistor PNP	MOT	2N4125	T04220	4
R1-4	Resistor, Carbon 22K, 1/4W, 5%	AB		R01775	4
R5-8	Resistor, Carbon 15K, 1/4W, 5%	AB		R01765	4

Count Chain (33-06070) Mother Board Parts List

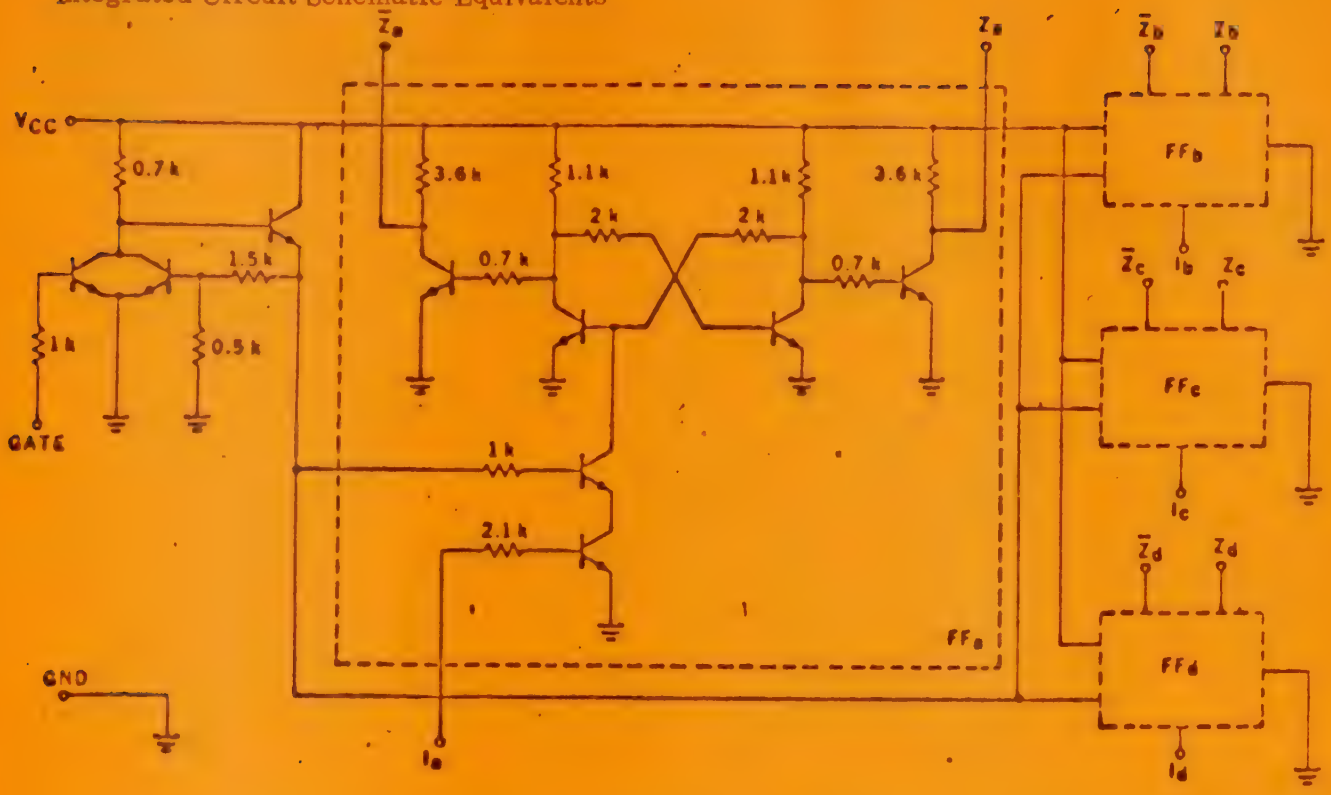
Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
CR1-3	Diode	SOL	2A100	D06540	3
CR4-9	Diode	ITT	1N3605	D04980	6
DS1, 2	Lamp, Overflow and Minus Indicator	GE	327	L00650	2
J1-5	Connector 18 pin	Cinch	252-18-30-160		5
Q1, 6	Transistor NPN	FAI	2N4274		2
Q2-5	Transistor PNP	FAI	2N3640	T04090	4
Q7, 8, 11	Transistor PNP	MOT	2N4125	T04220	3
Q9, 10	Transistor NPN	MOT	2N4123		2
R1-9	Resistor, Carbon 68K, 1W, 5%	AB		R03095	9
R10, 26, 37	Resistor, Carbon 390Ω, 1/4W, 5%	AB		R01635	3
R11, 25	Resistor, Carbon 3.9K, 1/4W, 5%	AB		R01720	2
R12, 13, 23, 24, 26	Resistor, Carbon 2.7K, 1/4W, 5%	AB		R01705	5
R14	Resistor, Carbon 47K, 1/4W, 5%	AB		R01795	1
R15, 29	Resistor, Carbon 8.2K, 1/4W, 5%	AB		R01750	2
R16, 18, 30	Resistor, Carbon 1K, 1/4W, 5%	AB		R01670	3
R17	Resistor, Carbon 270Ω, 1/4W, 5%	AB		R01620	1
R19, 28	Resistor, Carbon 10K, 1/4W, 5%	AB		R01755	2
R20	Resistor, Carbon 22K, 1/4W, 5%	AB		R01775	1
R21	Resistor, Carbon 3.3K, 1/4W, 5%	AB		R01715	1

Count Chain Mother Board Parts List (continued)

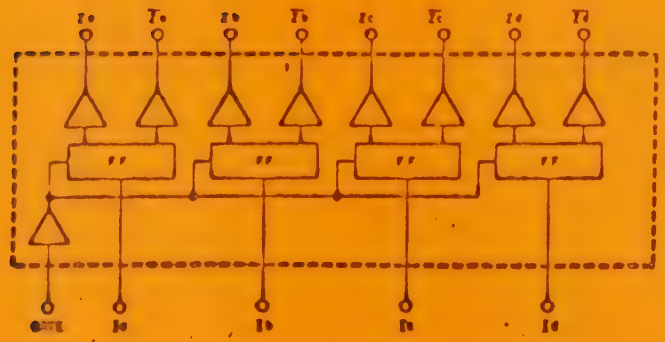
Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R22, 31	Resistor, Carbon 100Ω, 1/4W, 5%	AB		R01585	2
R27	Resistor, Carbon 820Ω, 1/4W, 5%	AB		R01665	1
R32	Resistor, Carbon 5.1K, 1/4W, 5%	AB		R01730	1
R33, 35	Resistor, Carbon 2.2K, 1/4W, 5%	AB		R01695	2
R34	Resistor, Carbon 120Ω, 1/4W, 5%	AB		R01590	1
R38	Resistor, Carbon 470Ω, 1/4W, 5%	AB		R01640	1
R39	Resistor, Carbon 4.7K, 1/4W, 5%	AB		R01725	1
R40	Resistor, Carbon 1.8K, 1/4W, 5%	AB		R01685	1
V1-9	Numerical Display Tube	National	NL840		9
XDS1	Holder, Lamp (Overflow)	Sloan	855SI-W-9-DS with O symbol		1
XDS2	Holder, Lamp (Minus)	Sloan	855SI-W-9-DS with - symbol		1
XV1-9	Socket	National	RTS-18		9

The following Resistors are also mounted on the Mother Board and are part of the Discriminator Circuits, see Schematic D-11-04814.

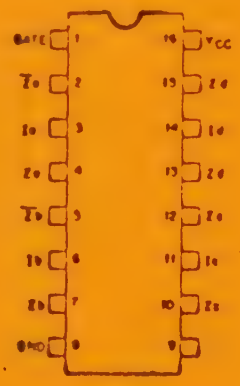
	Resistor, Carbon 150Ω, 1/4W, 5%	AB		R01595	1
	Resistor, Variable 200Ω	Beckman	62P-R200	P01455	1



Schematic Diagram Buffer Storage Unit CμL 9959



BLOCK DIAGRAM



BASE CONNECTIONS

GATE	I	Z	$\bar{Z}$
L	L	L	H
L	H	H	L
H	ANY	@	@

H = HIGH
L = LOW
@ = THE STATE ASSUMED PRIOR TO "GATE HIGH" IS MAINTAINED

TRUTH TABLE

Block Diagram and Pin Number Functions CμL 9959

Model 796

Decade Up Counter

MC780P • MC880P

Integrated Circuit Schematic Equivalents

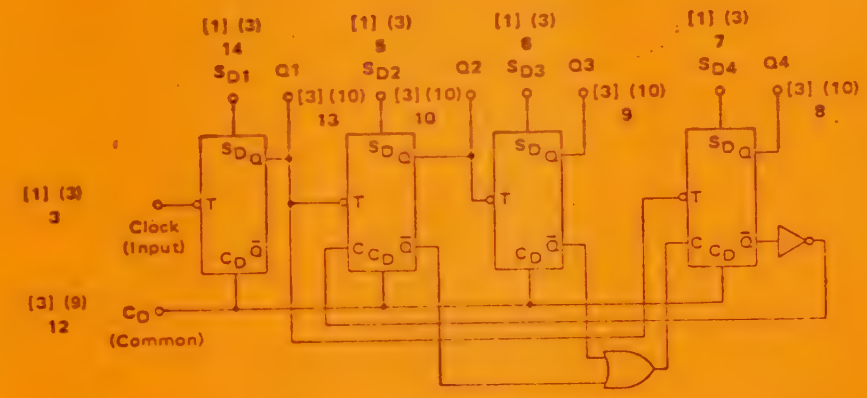
The MC780P/MC880P is a monolithic decade up counter consisting of four flip-flops internally interconnected. A common direct clear is provided to return all outputs to the logical zero level. Individual direct set inputs are provided to set the counter to any specific count.

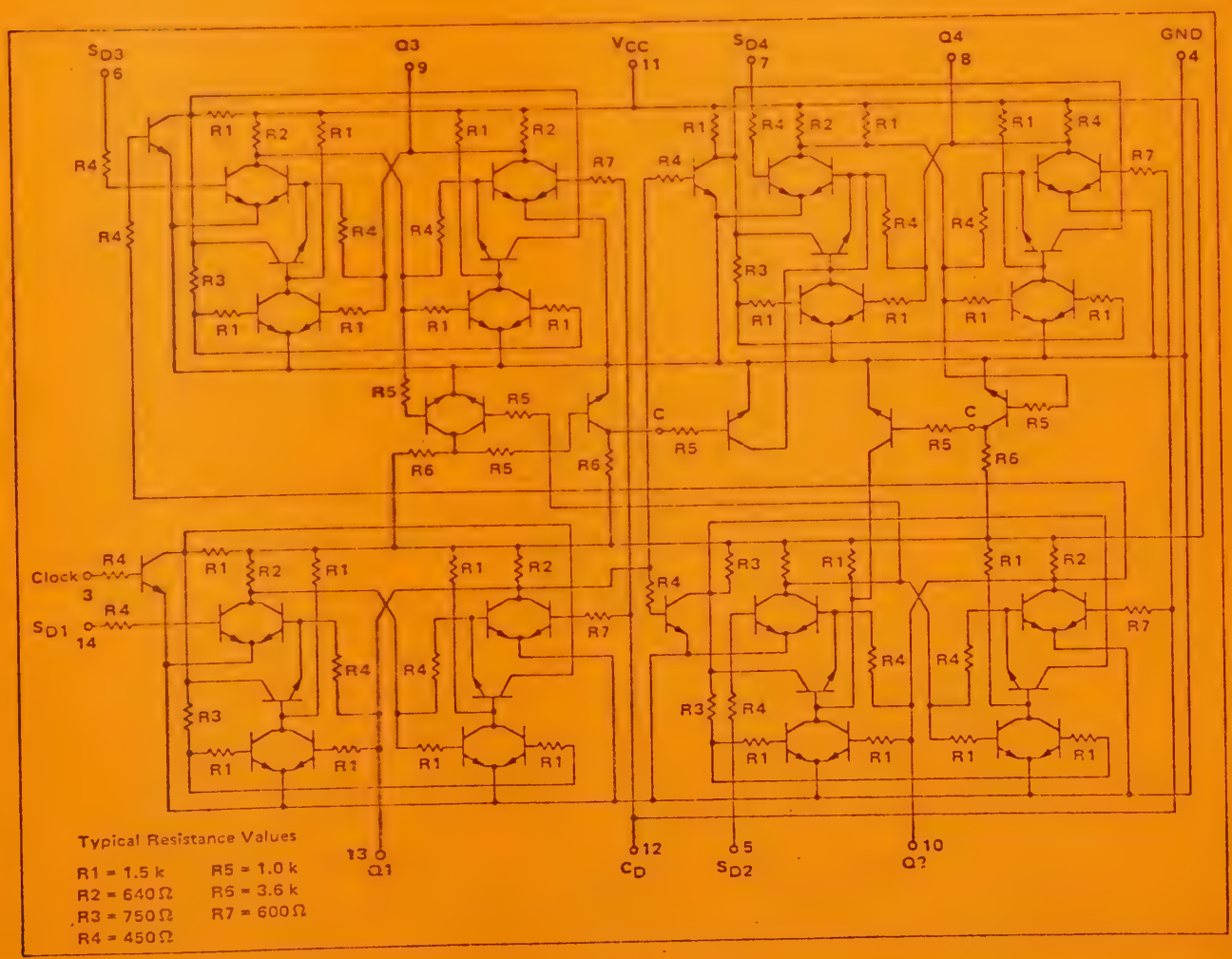
DECODING LOGIC

0	$\bar{A}$	$\bar{B}$	$\bar{C}$	$\bar{D}$
1	A	$\bar{B}$	$\bar{C}$	$\bar{D}$
2	$\bar{A}$	B	$\bar{C}$	$\bar{D}$
3	A	B	$\bar{C}$	$\bar{D}$
4	$\bar{A}$	$\bar{B}$	C	$\bar{D}$
5	A	$\bar{B}$	C	$\bar{D}$
6	$\bar{A}$	B	C	$\bar{D}$
7	A	B	C	$\bar{D}$
8	$\bar{A}$	$\bar{B}$	$\bar{C}$	D
9	A	$\bar{B}$	$\bar{C}$	D

P_D = 250 mW typ
f = 4.0 MHz
Counting Frequency

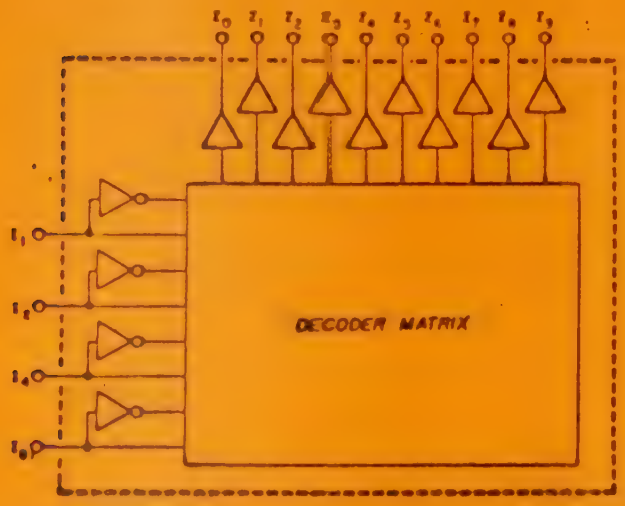
Number in parenthesis indicates loading factor for mW MRTL.
Number in brackets indicates loading factor for MRTL.





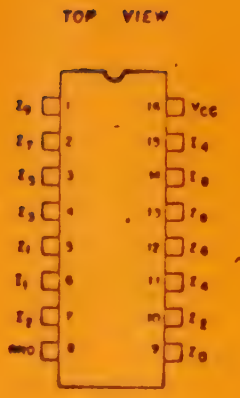
Typical Resistance Values

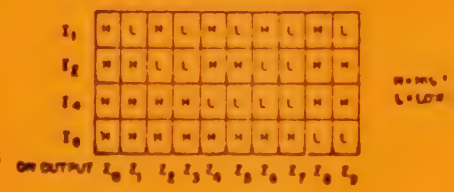
R1 = 1.5 k
R2 = 640 Ω
R3 = 750 Ω
R4 = 450 Ω
R5 = 1.0 k
R6 = 3.6 k
R7 = 600 Ω



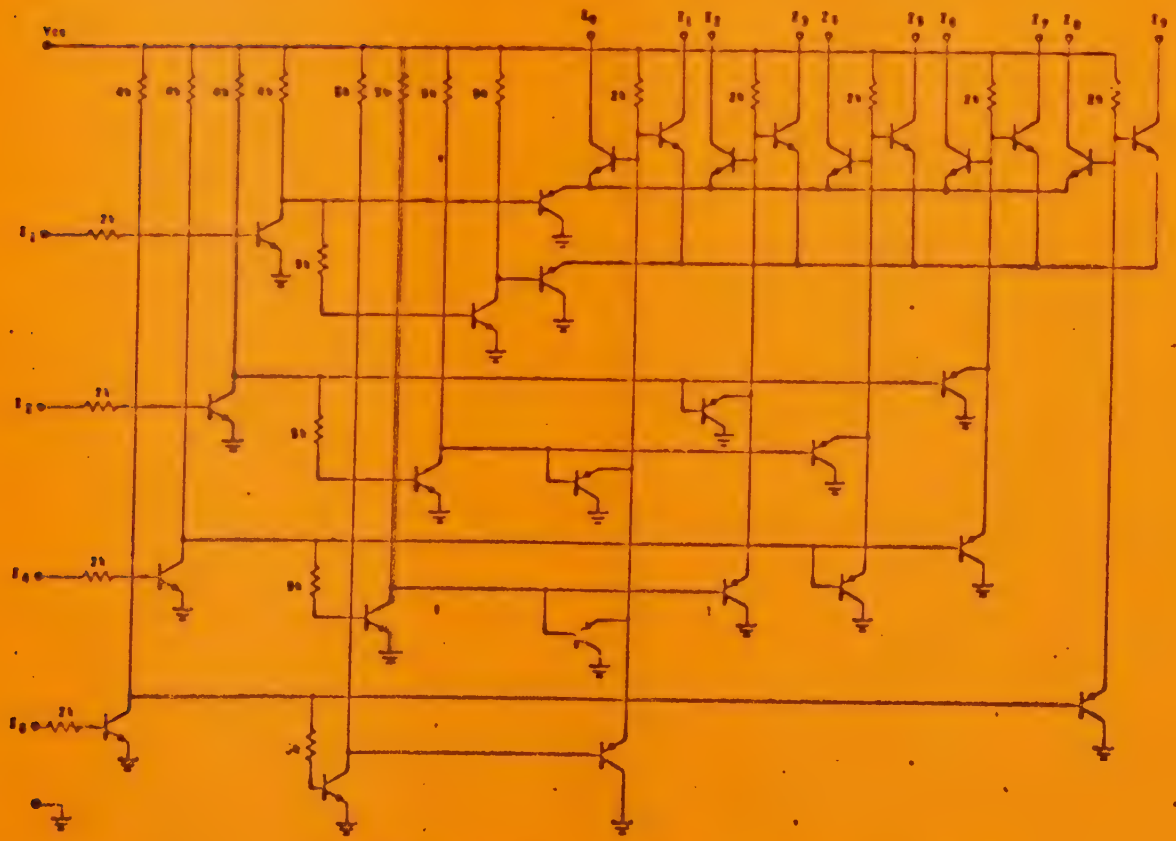
BLOCK DIAGRAM

Block Diagram and Pin Number Functions CμL 9960

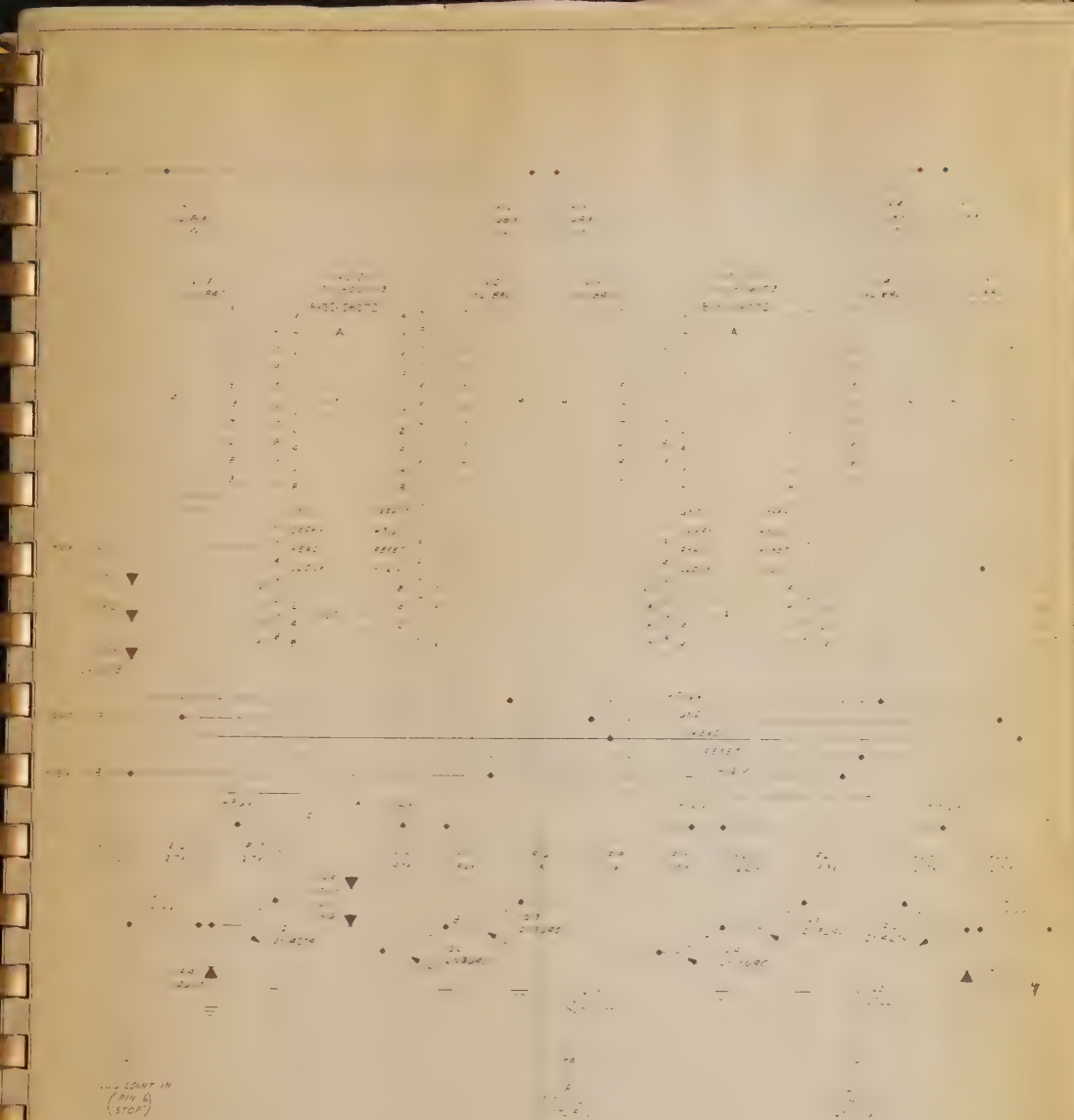




TRUTH TABLE



Schematic Diagram Decimal Decoder CμL 9960



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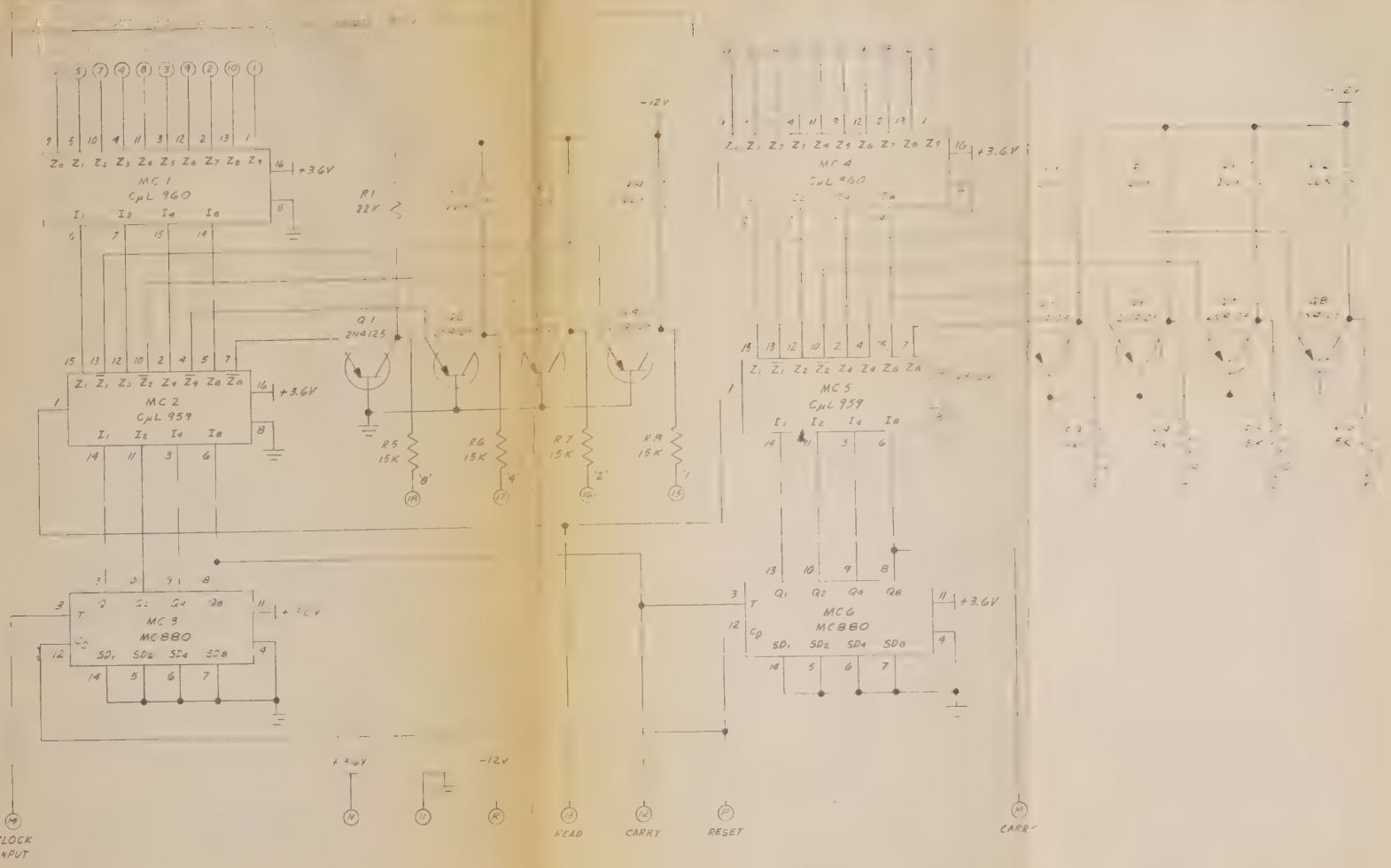
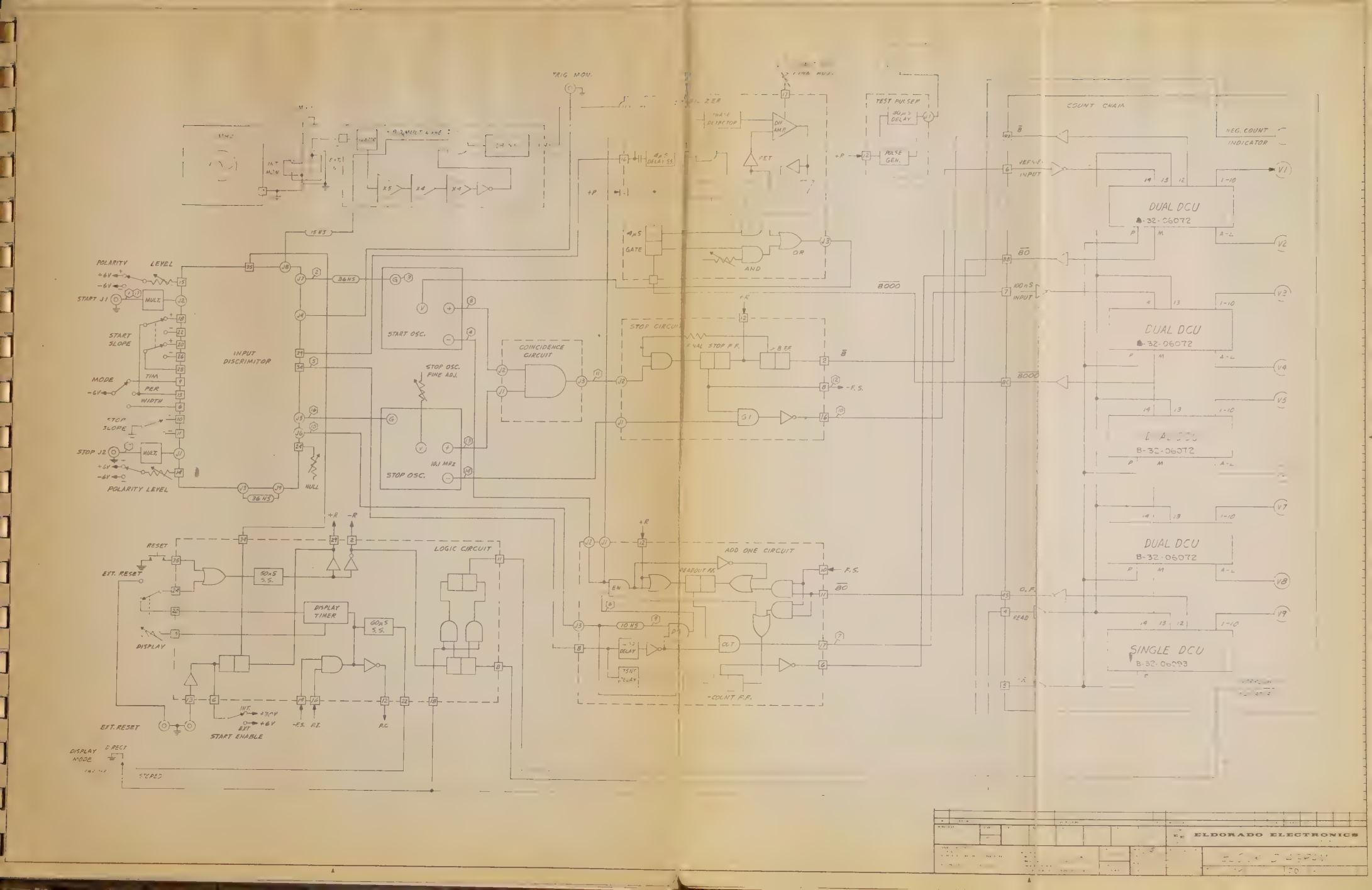

MC 1
CμL 960
MC 2
CμL 959
MC 3
MC880
MC 4
CμL 960
MC 5
CμL 959
MC 6
MC880
R1
22K
Q1
2N4125
R5
15K
R6
15K
R7
15K
R8
15K
+3.6V
-12V
CLOCK
INPUT
READ
CARRY
RESET
CARRY

| | | |


TRIG MON.
POLARITY
LEVEL
+6V
-6V
START J1
MULT.
START SLOPE
INPUT DISCRIMITOR
MODE
TIM
PER
WIDTH
STOP SLOPE
STOP J2
POLARITY LEVEL
NULL
15 NS
36 NS
START OSC.
STOP OSC.
STOP OSC. FINE ADJ.
10.1 MHz
COINCIDENCE CIRCUIT
4 nS GATE
AND
OR
4 nS DELAY SS
TEST PULSER
30 μS DELAY
PULSE GEN.
DIF AMP.
FET
STOP CIRCUIT
FINAL STOP F.F.
B F.F.
F.S.
G1
+R
-R
RESET
EXT. RESET
50 nS S.S.
DISPLAY TIMER
60 μS S.S.
DISPLAY
LOGIC CIRCUIT
INT. +3.4V
EXT +6V
START ENABLE
-F.S.
P.G.
DISPLAY MODE
DIRECT
STORED
ADD ONE CIRCUIT
READOUT FF
EN
10 NS
DELAY
OUT
-COUNT F.F.
COUNT CHAIN
NEG. COUNT INDICATOR
REVERSE INPUT
100 nS INPUT
O.F.
READ
DUAL DCU
B-32-06072
SINGLE DCU
B-32-06093
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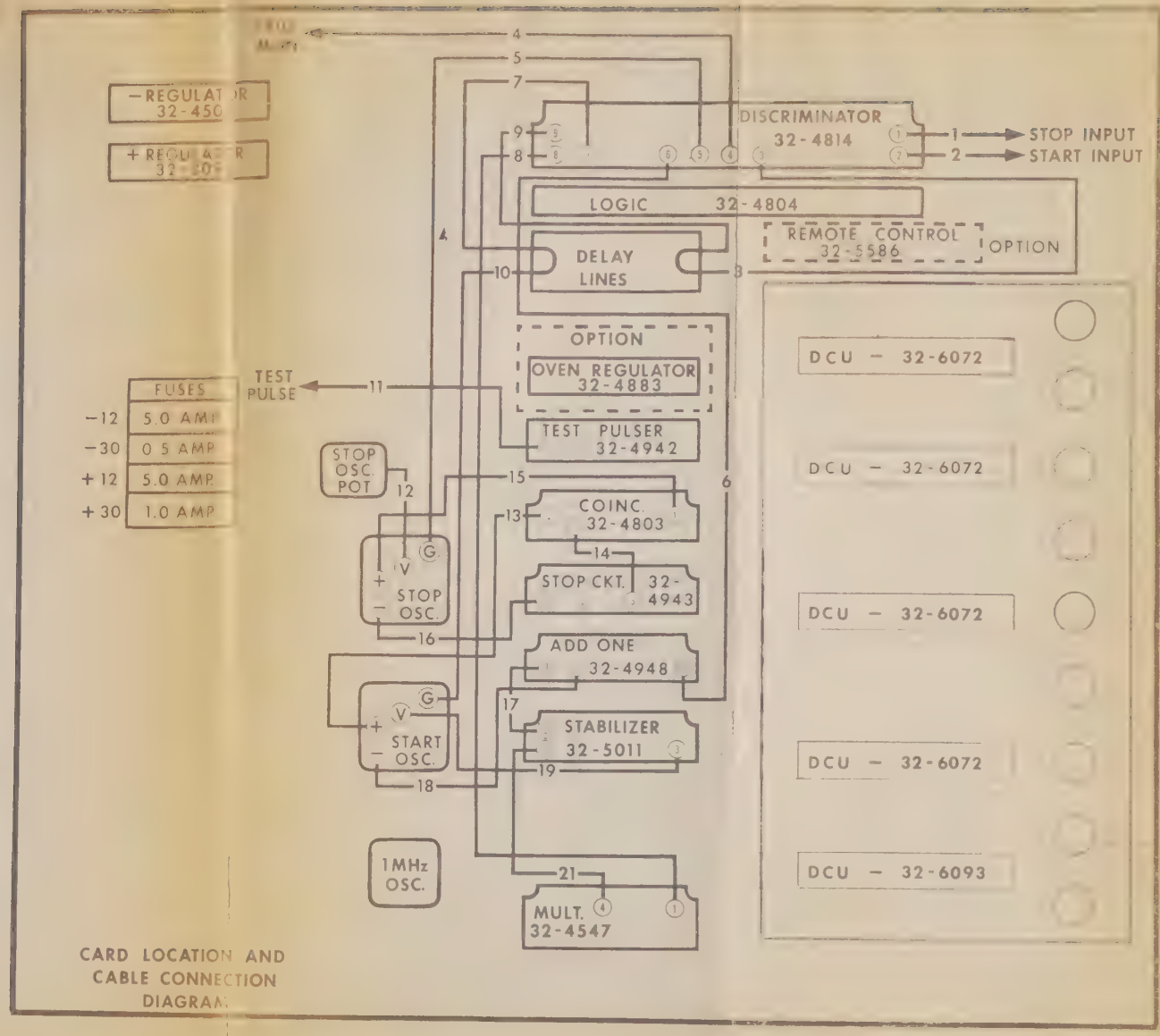

CARD LOCATION AND CABLE CONNECTION DIAGRAM

WARNING

LETHAL VOLTAGES EXIST WITHIN THIS UNIT. THE 115 OR 230 V ac IN THE POWER SUPPLY AND THE CRYSTAL OVENS AND THE 330 V dc DISPLAY VOLTAGE IN THE POWER SUPPLY, THE DISPLAYS, AND THE TEST PULSER ARE DANGEROUS TO LIFE AND LIMB. APPROACH THESE CIRCUITS ONLY WITH GREAT CARE.

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Complete the RMA card and enclose with the returned instrument. To obtain RMA number call or write to:

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Thank you,
Publications Department

1. Instrument Model_____. Serial Number _____
2. Do you operate ☐ or maintain this instrument ☐ ?
3. After reading the Specifications and Introduction Section did you feel that you had an adequate idea of the instrument's capabilities? ..... Yes ☐ No ☐
4. After reading the Operating Instructions were you able to operate the instrument to your satisfaction? ..... Yes ☐ No ☐
5. Were you able to calibrate the instrument with the calibration procedure? ..... Yes ☐ No ☐
6. Are you able to find the information you need on replacement parts in the parts list? ..... Yes ☐ No ☐
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- ☐ Time Code Instrumentation
- ☐ Computer and Data Terminals
- ☐ Frequency Counters
- ☐ Microwave Frequency Counters
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- ☐ Digital Delay Generators
- ☐ Digital Volt/Ohm Meters
- ☐ Power Pack
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Eldorado instruments are warranted during a period of one year from date of shipment to original purchaser to be free from defects in material and workmanship. The liability of Eldorado under this warranty is limited to replacing or repairing any instrument or component thereof which is returned by Buyer and has not been subjected to misuse, neglect, improper installation, repair, alteration, or accident. Eldorado shall have the right of final determination as to the existence and cause of a defect. In no event shall Eldorado be liable for collateral or consequential damages. This warranty is in lieu of any other warranty, express, implied, or statutory, and no agreement extending of modifying it will be binding upon Eldorado unless in writing and signed by a duly authorized officer.

RECEIVING INSPECTION

Every Eldorado instrument is carefully inspected and is in perfect working order at the time of shipment. Each instrument should be checked as soon as received. If the instrument or packing case is damaged in any way or fails to operate, a claim should immediately be filed with the transportation company. In any case where damage occurs in transit, Eldorado's obligations under warranty are dependent on the customer's immediately notifying the carrier, so that inspection can be made and a claim filed.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Please specify both model and serial number in all correspondence concerning Eldorado instruments. Address all inquires regarding Eldorado instruments to your nearest sales representative or Marketing Manager, Eldorado Electronics Company, 601 Chalomar Road, Concord, California 94520.

This Manual is packaged with instrument Serial Number _____.

This instrument is a Model 796.

It contains options

Option C

Option D

Option E

Option J

Option L

Option N

Option P2

Option R1

Option R2

Option T

Option Y1

Option Y2

Option Y3

Option P/A

Option P/B

Option P/C

Option P/D

Option P/E

Special Modification Number _____.

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Schematic, Multiplier
Schematic, Input Discriminator D-11-04814
Schematic, Logic Circuit D-11-04804
Schematic, 25 MHz DCU D-11-03968
Schematic, 2.5 MHz DCU D-11-03967
Schematic, 250 kHz DCU D-11-03966
Schematic, Memory Readout D-11-04962
Schematic, Test Pulser C-11-04942
Schematic, Coincidence Circuit B-11-04803
Schematic, Stop Circuit C-11-04943
Schematic, Add One Circuit D-11-04948
Schematic, Stabilizer Circuit D-11-05011
Schematic, 80 MHz Multiplier and VHF Divider D-11-05211
Schematic, Start Up Oscillator C-11-03440
Schematic, Reference Oscillator (STD) A-11-04979
Schematic, Option D and E Oven Power Regulator A-11-04949
Schematic, Power Supply D-11-04917
Schematic, Remote Slope and Mode Control C-11-05586
Schematic, Remote Slope and Mode Control Option J C-11-05587
PCB Layout, M-25-04905
Above Chassis Cable List, Table 7-1

SECTION 1

INTRODUCTION AND SPECIFICATIONS

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The Eldorado Electronics Model 796 Time Interval Counter is a precision electronic instrument. It is capable of measuring time intervals from zero to one second with resolution of one nanosecond. It is capable of measuring the time interval between two electrical signals, the width of a pulse, or the period of a waveform. Its trigger circuitry is modern and versatile - - its trigger slope can be selected and its trigger level can be set anywhere from -128V to +128V, excluding the region within 100 mV of ground, by front panel controls. In fact, all the important controls are on the front panel. There are no plug-ins. There is no minimum rise time requirement. There is a single input connector for all frequencies.

The unit's electrical and mechanical specifications are listed in Table 1.1.

Normally, the Model 796 is calibrated in nanoseconds. 0 to 999,999 nanoseconds, optionally expandable to 999,999,999 nanoseconds, or one scant second. Models are available on special order which are calibrated in feet, yards, or meters.

Other options include remote control, highly stable internal oscillators, output adapters for various printers, and a power supply operable in airplanes or other 400 Hz environments. The Model 796EY2, a 796 with a very stable oscillator and eight decades, has been assigned federal stock number FSN 6625-017-9033YA.

The options are discussed in greater detail in Table 1-2.

1.1.1 Applications

Instrument Calibration: The Model 796 has resolution at least an order of magnitude better than that of most contemporary test instruments. It can be used to calibrate pulse generators, delay generators, oscilloscopes, less exotic Time Interval Counters, and other equipment.

Delay Line Calibration: The Model 796 is useful for quickly and accurately setting variable delay lines. Its fast repetition rate permits fast operator adjustment of such delays, even in production environments.

Cable Length: Ideally, the Model 796 can measure the electrical length of a cable of known velocity factor with a resolution of 6" and range of from 6" to 500,000,000 feet, assuming unity velocity factor.

Cable Fault Location: Similarly, the Model 796 may be used to locate short or open faults in otherwise inaccessible cables, the procedure is described in Eldorado's application note, Volume II., #4. The resolution is again theoretically 6", but this is limited by the high frequency characteristics of the cable involved. Utility cables, in particular, leave much to be desired in terms of constant impedance. The accuracy of the system is in practice limited to about 3". This is not unreasonable - - it is at least as accurate and far simpler to use than any other method presently employed.

Ranging: The special distance-calibrated 796's are eminently suited to radar and laser ranging. With a proper laser system, the 796 could range the moon to the nearest meter.

Coincidence Detection: The Model 796's null and "negative time" capabilities allow it to be used to check the simultaneity of pulses and to accurately match delay lines.

Period Measurements: The Model 796 can be used as a frequency meter. Its output is accurate to ±1 Hz at 100 kHz.

The Model 796 is unique in its accuracy, reliability, and versatility. Its uses are many and varied.

1.2 INTRODUCTION TO THEORY OF OPERATION

A Time Interval Counter measures the time between two events. In most such instruments, the output of a precision oscillator is gated ON by the first event and OFF by the second. While the gate is ON, the output of the oscillator is counted in an accumulator, and later displayed or printed. The resolution of this sort of counter is proportional to its basic count frequency. Because the ON and OFF signals arrive at times of unknown phase angle relative to that of the internal oscillator, it is possible for the counter to accumulate an extra count or delete a valid one if the gating signal occurs almost simultaneously with the oscillator transition.

Thus, if the Model 796 were designed conventionally, it would have an extremely accurate 1 GHz oscillator, a fast gate, and a counter capable of running at 1 GHz. This sort of circuitry is on the uncomfortable edge of the state of the art. Further, it would still have the normal ± one count error.

The Model 796 uses timing oscillators in known phase with the input signal, a vernier (or "beat") nanosecond counter, and an elaborate though reliable network of logic to achieve 1 ns resolution without extremely fast circuitry. The fastest counting rate in the unit is 10.1 MHz. Further, the 796 eliminates the count error - its readings are ±0.5 ns, not including the stability of the internal oscillator.

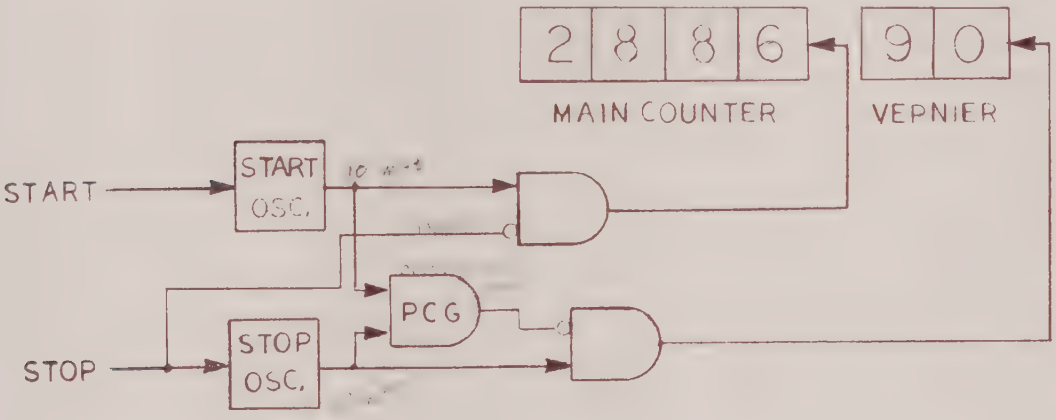


FIGURE 1.2.1

Basic Block Diagram

Figure 1.2.1 is a very simplified block diagram of the Model 796. The first event to be timed appears at the Start Input and gates ON the Start Oscillator, a 10.0 MHz clock. The oscillator is designed to start exactly in phase with its input signal. Thus, when it is started, it will start counting 100 ns intervals exactly in time with the input. The output of the Start Oscillator is counted by the main counter - - a series of Decimal Counting Units (DCU's) representing units of 100 ns. The decades representing 1 ns and 10 ns (the Interpolation Counter) are kept at zero until the Stop signal arrives.

When a Stop signal arrives, signifying the end of the interval to be measured, the count to the main counter is stopped. The counter now holds the number of hundreds of nanoseconds that passed between the two signals. This count is correct to +0, -100 ns.

(One count is 100 ns). This is to say, if the correct time is 2299 ns, the counter may hold 2200 ns or 2100 ns but not 2300 ns.

Meanwhile, the Stop signal has started the Stop Oscillator, a 10.1 MHz clock. This oscillator, also, starts exactly in phase with its input. Thus, it starts out of phase with the Start Oscillator by a time equal to the unmeasured part (the last two digits) of the input time. Now, the output of the Start Oscillator has a period of 100 ns, and the Stop Oscillator one of 99 ns. The Stop Oscillator "catches up" with the Start Oscillator by one nanosecond per cycle. They will be exactly in phase for a moment in 10 μs or less - - after a number of cycles equal to the number of nanoseconds remaining uncounted.

The output of the 10.1 MHz Oscillator is counted by the vernier counter, the two least significant digits of the count chain. Simultaneously, the two oscillator outputs are differentiated and compared by the Picosecond Coincidence Gate. When the outputs are simultaneous (the oscillators in phase) the count to the interpolator is stopped. The Add One logic now sees whether the main (100 ns) counter has missed a count. If so, it supplies one of its own, and the reading becomes correct.

Figure 1.2.2 Illustrates the Frequency vernier interpolation principle. This method of measuring time is directly analagous to a vernier calipers' measurement of distance.

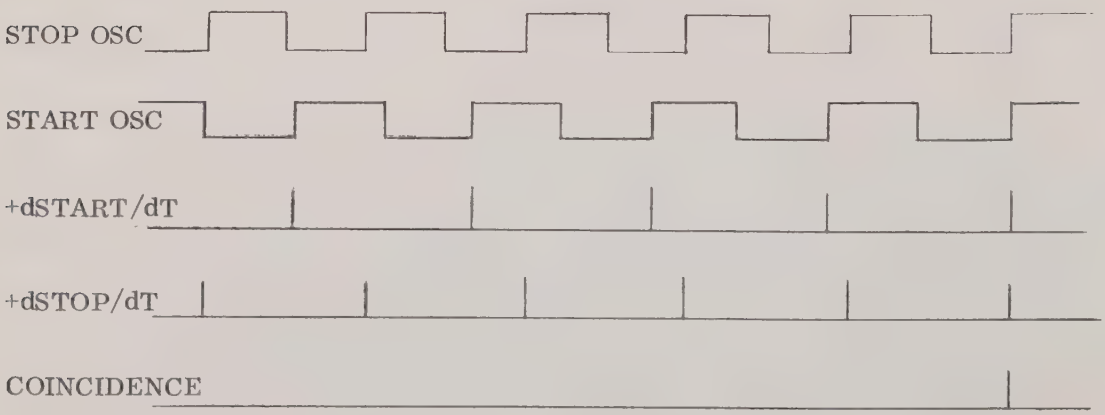


FIGURE 1.2.2

The Model 796 includes a highly versatile input circuit. It is capable of triggering on any positive or negative voltage from 0.1V to 128V. It can trigger on a selected polarity and slope. The input attenuator is set in binary steps to facilitate measurement from the 50% levels of pulses. On any position of the attenuator, the trigger level is variable over a range of at least ten to one.

The input circuitry can operate in any of three modes:

TIM (A-B) - The instrument measures the time interval between signals at A and B. The Start and Stop inputs are fully and independently adjustable.

The instrument can be adjusted to trigger at virtually any point on each of two pulses, or, with proper tee-connection hardware, any two points on one pulse. Thus it can be used for accurate and versatile pulse width measurement as well as 10%-90% rise and fall time measurements.

In this mode the instrument can accept a Stop signal up to about 10 ns before a Start signal. Such "negative time" measurements are displayed as a minus sign followed by the 100 ns complement of the "time" thus measured. This feature is particularly useful when the 796 is used as a null meter to synchronize pulses or match delays.

PERIOD (A) - The instrument measures the time between two successive points on the A input at the same trigger voltage and slope. This mode is most useful for repetitive signals.

Only the controls associated with the A input are active in this mode. Interlock logic is provided to allow the timer to accept Start and Stop inputs simultaneously without confusing itself. This limits the capacity of the instrument to periods of 50 ns or more.

WIDTH (A) - In this mode, the instrument measures the time between the A input's crossing a selected trigger level at first one slope and then the other. The A input controls select the trigger level and the Start slope - - the stop slope is automatically determined as the opposite of the start slope.

Measurements of pulses of less than 20 ns width are not possible in this mode due to the finite recovery time of the trigger circuitry. Such pulses can, however, be measured in the TIM mode if the pulse is applied to both inputs simultaneously.

TABLE 1-1

SPECIFICATIONS

MODEL 796 TIME INTERVAL COUNTER

FUNCTION:	Digital Determination with 1 ns resolution of time interval, period, pulse width.
GENERAL SPECIFICATIONS:	
Modes:	
TIM	Measure time interval between two events. Start with plus or minus polarity and plus or minus slope and stop with independently selected plus or minus polarity and plus or minus slope.
PER	Measure duration of one input cycle. Start and Stop with same polarity and slope (either plus or minus polarity and plus or minus slope).
WIDTH	Measure duration of one pulse. Start with selected slope and stop with opposite. Start and Stop are the same polarity.
Minimum Time Measurement	
TIM	0 ns
PER	50 ns
WIDTH	20 ns
VISUAL PRESENTATION:	6 decades with options to 9 decades of long life digital display indicators with amber circularly polarized filter plus overflow and minus indicator. Reads in nanoseconds.
RESOLUTION:	1 nanosecond
ACCURACY:	1 ns ± oscillator stability to 10,000 μs; 1.5 ns 10,000 μs to 1 s ± oscillator stability.
OSCILLATOR STABILITY:	
Aging Rate	$+3 \times 10^{-8}$ per day after 30 days operation.
With Temperature	In normal laboratory environment of 16° C to 32° C (60° F to 90° F) after 30 minutes of operation, stability is 2×10^{-7} per ° C change of ambient temperature. Over entire operating temperature range (0° C to 52° C) total drift will not exceed 20 ppm (0.002%).

INPUT CHARACTERISTICS:

Input Connector	Front panel mounted BNC.
Input Impedance	50 ohms; reflection from 100 ps step less than 10%.
Trigger Level	0.1 to 1.0V continuously variable times multiplier setting.
Multiplier	X1, X2, X4, X8, X16, X32, X64, X128 of trigger level.
Dynamic Range	10:1 minimum on any attenuator position.
Maximum Power	0.25 watt continuous or 250V for 1 μs.
Rise Time Requirements	None
Minimum Trigger Requirements	
TIM (Time Interval) A-B	0.1V peak - For optimum trigger performance inputs should exceed trigger level by 250 mV peak.
PERIOD (A)	0.1V peak.
WIDTH (A)	0.1V plus trigger setting (0.2V peak minimum).
Trigger Stability	
With Temperature	<10 mV change from 0 - 52° C.
With Rise Time	<20 mV change from dc to 1 ns.
With Pulse Width	Infinite to 20 ns - no change. 1 ns wide pulses increase minimum input requirements to 0.5V peak.
Maximum Input Voltage	10V times multiplier setting up to 250V. Maximum 1/4 watt dissipation into 50Ω.

DIGITAL RECORDER OUTPUT

Data Word	1-2-4-8 positive true, negative level BCD; for each data digit "0" = -10V nominal, "1" = -0.3V nominal; 6.8k internal resistance.
Print Command	Negative going step at end of count cycle from 0V to -12V nominal with fall time <1 μs; 1k ohm maximum internal resistance. Return to 0V remains longer than 50 μs. Duration of print command is equal to the display time, 100 ms minimum to 5 s maximum. On EXT RESET its length can be as short as 9 μs.
Reset Inhibit	Requires an inhibit level of 0V if supplied from <1k ohms resistance to +30V at up to 30k ohms resistance.

Inhibit Release	Requires a release level of 0V to -6V if from >20k ohm resistance or -6V to -30V from any source impedance.
Overflow and Minus Indication	One data digit where 0 represents no overflow and no minus; 1 represents overflow and 2 indicates minus (overflow and minus cannot occur simultaneously since maximum negative (minus) reading cannot exceed approximately 20 ns). Data is presented in same code and same levels as Data Word.
Compatibility	Clary 7000, with option II logic and standard print command; CMC 410A, with logic option 4a; Franklin 1200 with reverse logic; HP 562A with option 22 logic boards; 1 option 30 and 1 option 31 BCD input cable; HP 5050A with option 01 installed and with 2 each option 32 input cables; Monroe 10-40-M1-0-K.
Printing Format	Standard, ZOOOXXXXXX; Y1, ZOOXXXXXXX; Y2, ZOXXXXXXXX; Y3, ZXXXXXXXXX. X - Data, O = wired to print 0, Z = Overflow or minus reading. Overflow prints 1, Minus prints 2.

FRONT PANEL CONTROLS:

Power Off - Direct - Store	Rotary switch controls instrument power and chooses "store" or "follow" operation of digital readout.
Reset	Pushbutton.
Null	Screwdriver adjustment for zero setting or cable compensation.
Display	Single turn potentiometer with switch position at full cw, varies display time from approximately 0.1 s at the ccw position to 5 s at full cw, and until EXT RESET (or manual) in cw switched position.
Mode	Selects TIM (A-B), PER (A), or WIDTH (A) by 3 position rotary switch.
Start (A) Input Trigger Level Control	Single turn potentiometer varying the trigger point from 0.1V through 1V on times 1 position of the Multiplier Control.
Start (A) Input Multiplier Control	Multiplies trigger level by X1, X2, X4, X8, X16, X32, X64, and X128. Accuracy ±2%.
Start (A) Slope Switch	Selects + or - slope for start.

Start (A) Polarity Switch	Selects + or - polarity for start.
Stop (B) Input Trigger Level Control	Same as Start Input Trigger Level Control.
Stop (B) Input Multiplier	Same as Start Input Attenuator.
Stop (B) Slope Switch	Same as Start Slope Switch.
Stop (B) Polarity Switch	Same as Start Polarity Switch.

REAR PANEL:

CONTROLS AND CONNECTORS

INT. MON. - EXT. IN.	Recessed slide switch permits monitor of internal 1 MHz crystal (1V rms from 500 ohms) on INT. position or accepts external 1 MHz standard supplying 1V rms into 10k ohm in EXT. position.
EXT. Reset	BNC type UG1094 accepts negative pulse -4-10V into 1k ohm, 1 μs minimum width. Maximum rep rate 10 kHz.
Test Pulse	BNC type UG 1094 supplies test pulse to external calibrating equipment. Pulse is +15V minimum into 50 ohms, 8 ns nominal width, <2 ns rise. Occurs 30 μs nominal after end of reset.
Start Enable	Recessed slide switch chooses INT or EXT signal. External signal applied to BNC type UG 1094. Signal required is -3V minimum to -10V maximum, 1 μs minimum width into 10k ohms.
Trigger Monitor	BNC type UG 1094 supplies pulses at start and stop trigger points. Pulse is >.5V with <5 ns rise and >10 ns wide into 50 ohms.
Data Output	Amphenol 57-40500 50 pin connector to external data handling device. Mating connector not furnished.
115/230	Recessed slide switch chooses 115 or 230V operation.

PHYSICAL SPECIFICATIONS

Size	Nominal 5-1/4" high by 20-5/8" deep x 16-3/4" wide. With rack mounting ears attached, the instrument shall conform to RETMA Std. SE-102 providing for a vertical height of 5-7/32" ± 1/64" and a horizontal mounting width of 19" ±1/64".
Weight	40 lbs net; 58 lbs shipping.

Power Requirements	115V ±10%, 48-62 Hz, 140 watts. Permanently attached 6' power cord terminating in standard 3 prong plug.
ACCESSORY ITEMS	2 each instruction manuals 1 each 3-2 ac line adapter 2 each extender boards 2 each rack ears
PAINT SPECIFICATIONS	
Front and Rear Panel	Light gray color 26492 per FED STD 595 non-textured.
Silkscreen	Blue-black, color no. 26042, per FED STD 595.
Front and Rear Bezels	Blue-gray color per FED STD 595, color no. 26321, textured finish.
Left and Right Side Gussets	Lt. gray color per FED STD 595, color no. 26492, textured finish.
Top and Bottom Covers	Lt. gray color per FED STD 595, color no. 26492, textured finish.
Rack Ears	Blue-gray color per FED STD 595, color no. 26321.

TABLE 1-2

TABLE OF OPTIONS

Option C

Internal crystal oscillator, provides oscillator stability of:

Short Term: 5×10^{-8} per day (average).

Long Term (aging rate): 3×10^{-7} per week after 24 hours.

Temperature: $\pm 5 \times 10^{-9}$ per ° C (0° C to 52° C).

Option D

Internal crystal oscillator, provides oscillator stability of:

Short Term: $\pm 5 \times 10^{-10}$ peak to peak per 10 s, measured over a 60 s period of 5 consecutive readings, at constant temperature.

Long Term (aging rate): Subject to the following stabilization times:

(a) 3×10^{-9}/day
(b) 9×10^{-8}/month

Time Off Power	Days to Restabilize
Up to 7 days	3 maximum
8 through 30 days	4 to 14 maximum
30 days or more	15 to 30 maximum

Ambient: 2×10^{-10}/° C maximum from -20° C to +55° C.

Warm Up and Stabilization Time: From +25° C ambient to final stabilized frequency:

(a) Within 1.5×10^{-7} in 30 minutes
(b) Within 2×10^{-8} in 60 minutes

Option E

Internal crystal oscillator, provides oscillator stability of:

Short Term: $\pm 5 \times 10^{-10}$ peak to peak per 10 s, measured over a 60 s period of 5 consecutive readings, at constant temperature.

Long Term (aging rate): Subject to the following stabilization times:

(a) 1×10^{-9}/day
(b) 3×10^{-8}/month

Time Off Power	Days to Restabilize
Up to 7 days	3 maximum
8 through 30 days	4 to 14 maximum
30 days or more	15 to 30 maximum

Ambient: 2×10^{-10}/° C maximum from -20° C to +55° C.

Warm Up and Stabilization Time: From +25° C ambient to final stabilized frequency:

(a) Within 1.5×10^{-7} in 30 minutes
(b) Within 2×10^{-8} in 60 minutes

Option J

Remote Programming of MODE, POLARITY, and SLOPE switches. Provides remote trigger level control with remote 50 ohm potentiometer.

Option J (continued) Option J adds fourth position to MODE switch labeled REMOTE and adds rear mounted Amphenol 57-40240 24 pin connector labeled REMOTE CONTROL. Mating connector Amphenol 57-30240 is furnished with option.

Option L Provides power connectors on the front panel for two Tektronix P6045 FET probes.

Option N Provides for input connectors on rear panel only.

Note: Options L and N are not available simultaneously.

Option P2 Provides compatibility for all printers previously listed and adds the Beckman, Model 1453.

P2 changes the print command so that the return to zero between measurements is equal to or greater than 15 ms. With option P2 installed, the maximum recycle rate of the Model 796 on external or internal reset is limited to 60 Hz rather than 10 kHz.

Option R1 Front panel special paint, specify color per FED STD 595.

Option R2 Special paint, front panel, bezel, and rack ears.

Option T 115/234 Vac ±10%, 50-400 Hz operation.

Option Y Expands display to 7 digits (Y1), 8 digits (Y2), or 9 digits (Y3) with overflow and minus indicators for visual display and digital recorder output.

PRINTER CABLE OPTIONS:

P/A	Adapter cable for Beckman, Model 1453 (applicable Option P2 only).
P/B	Adapter cable for Clary, Model 7000, Franklin, Model 1200, or Monroe, Model 10-40.
P/C	Adapter cable for CMC, Model 410A.
P/D	Adapter cable for H-P, Model 562A.
P/E	Adapter cable for H-P, Model 5050A.

NOTE: The Model 796 can be modified for direct reading in feet, yards, and meters of free space. Specifications and prices are available on request.

CHAPTER 2

INSTALLATION

CHAPTER 2

INSTALLATION

2.1 GENERAL

This chapter discusses the unpacking, incoming inspection, and installation of the Eldorado Electronics Model 796 Time Interval Counter.

2.2 UNPACKING

The Time Interval Meter is packed with its accessory items in a specially designed corrugated-cardboard carton. Unpack it carefully and check for the following accessories:

(2) Instruction Manuals
(1) 3-wire/2-wire AC line cord adapter
(2) Extender boards
(2) Rack ears, with instrument mounting bolts

Look the instrument over carefully for obvious mechanical damage, or any indication that the instrument or its carton has been subjected to unusual abuse in transit. If such is noticed, inform the carrier immediately.

If any accessory items are missing and the package was not broken in transit, notify Eldorado immediately.

2.3 INCOMING INSPECTION

If you have a standard incoming inspection procedure for test equipment, by all means follow it. If the procedure involves removing circuit boards, to check, for example, for corroded contacts, it would be wise to skip that step. If you must pull the boards, be extraordinarily careful to replace them in their original sockets, to replace all top-connecting cables exactly as they were, not to disturb any trimmer adjustments, and not to bend inductors or otherwise misalign circuitry.

If you have no such standard procedure, simply look the instrument over closely. See that the knobs turn, and test-fit the connectors with their proper mates. Remove the cover and look to see that nothing is obviously broken, that all interior cables are connected and that all the boards are snug in their sockets. Visually check the display tubes - - see that none are cracked and that all are tightly in their sockets. See that any clamps for oscillators and electrolytic capacitors are fastened. Give the fan a twirl with your finger - - see that it rotates freely. See that the filter is clean. See that the fuses are intact. If all seems in order, replace the cover. NOTE: Cover screws need not be entirely removed. One turn is sufficient.

2.3.1 Incoming Confidence Check (To be performed by competent technical personnel.)

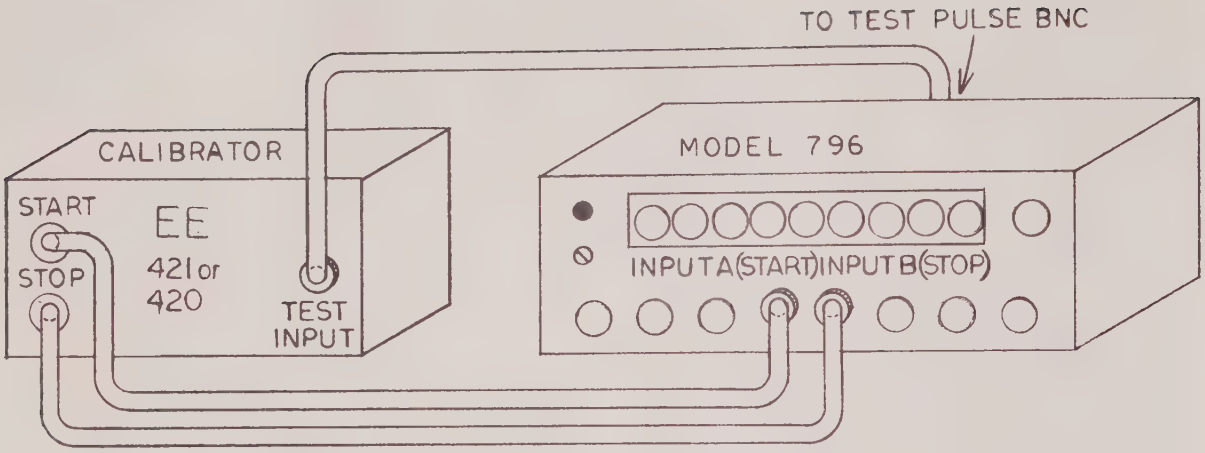
The instrument was in perfect operating condition when it was shipped. All its functions were tested, and it was well calibrated to excellent standards. The following procedure is designed to check the operation of the unit and to introduce operators to its functions.

If an Eldorado Electronics Model 420 or 421 calibrator is available, the instrument should be checked by procedure A, following. If no such tester is available, procedure B requires only a 1 MHz frequency standard which, in a pinch, can be supplied by the Model 796 itself.

Procedure A

1. Connect the line cord, after ascertaining that the 115/230 volt switch* is in the correct position. Turn the instrument on. See that the gas display tubes light up, and that the fan motor runs. Turn the Display Mode switch to DIRECT, press the Reset button, and see that all the display tubes show zeroes.
2. Connect the Model 420 or 421 as shown in figure 2.3.1. Let everything warm up for at least 4 hours, preferably longer.
3. Set the operating controls as listed in figure 2.3.1. Switch the Model 420 to the VARIABLE mode. No such switch is available or necessary on the Model 421.
4. Press the Reset button to start the system cycling. The Reset button, after 30 μs, sends a test pulse to the 420, which then produces two pulses set from 0 to 15 ns apart. The 796 measures this interval, resets, and sends another test pulse to the 420 which starts the cycle

* WARNING:
Never move the 115/230 Vac selector switch with line cord attached to the power line.



MODEL 796
SWITCH
POSITIONS

INPUT MULTIPLIER (A&B)	X4
TRIGGER LEVEL (A&B)	0.2
SLOPE & POLARITY (A&B)	+
DISPLAY TIME	MIN. (FULL CCW)
DISPLAY MODE	DIRECT
MODE	TIM

ACCESSORIES
REQUIRED

5 FEET RG 58/U TERMINATED EACH END W/ UG 88-/U CONN.

MODEL 420 ONLY- 2ea GR TO BNC ADAPTERS

NOTE:

DO NOT CONNECT MODEL 420 DC POWER CABLE TO MODEL 796

MODEL 420 TO BE IN VARIABLE DELAY MODE. SEE FIGURE 2.3.2

CALIBRATOR SETUP FIGURE 2.3.1

again. In the Min. position of Display Time, this happens at about 10 Hz. The Model 796 should be now indicating some time between 0 and 15 ns, as set by the 420. If not, check all connections and control settings, including those on the back panel.

5. Check the 796 over the full 0 to 15 ns range of the 420. See that it reads correctly. Flip the 1/3 ns switch and see that it does not affect any reading from 0 to 15 ns. Reverse the A and B inputs and check the -10 to 0 ns range.
6. If the instrument reads wrongly, set the delay of the calibrator at 15 ns and adjust the Null pot on the front panel (with a screwdriver) for a reading of 15 ns. See that 15 1/3 ns reads as 15 ns and that 14 1/3 ns reads as 14 ns. Trim Null till this is so. Check the readings from 0 to 5 ns. If they are wrong, refer to the calibration section of this manual.

Do not adjust any internal trimmers in the 796 unless you are very sure what you are doing. Hamhanded alignment can ruin the accuracy of the instrument as well as void the warranty.

Procedure B

1. Follow step 1 of procedure A.
2. Connect a 1 MHz frequency standard to input A.
3. Put the instrument in the PERIOD (A) Mode. Set polarity switches at + and trigger level as appropriate for the input signal - - about 50% of its peak voltage. Set Display Time at Min. and Display Mode to STORED.
4. Let the system run for 5 minutes.
5. Trim Null for a reading of 1000 -1+0 ns.
6. If the instrument will not so adjust, check the controls to see that it is triggering properly. Check the standard to find whether it is anywhere near 1 MHz. In a pinch, run a cable from the 1 MHz osc. jack on the back of the unit to the A input. If you cannot set the unit to 1000 ns, refer to the calibration section.

Once the Null pot is set, try measuring whatever signals you may have handy - - pulse generators, oscillators, and whatever. Try the instrument in each of its modes. Check for triggering on different input slopes and at different levels. Bear in mind that the

796 is probably much more accurate than any test generator you connect it to. Discrepancies between the calibrated and indicated times will usually be the fault of the input device. See that the Display Time is adjustable over a reasonable range. Satisfy yourself that the instrument is working and that you understand its operation.

2.4 INSTALLATION

The instrument is shipped equipped with rubber feet and a wire bail that can be flipped downward, to tilt the panel up.

It can be easily installed in a rack. Be sure that the back of the rack is sufficiently clear to allow a flow of cooling air to the fan on the back of the package. Remove the ornamental nylon screws from sides of the instrument and unpack the mounting ears from their plastic bag. Bolt the ears to the ends of the panel. Fit the unit to a 5 1/4" space in a standard 19" rack. Bolt it there and make the necessary cable connections.

2.4.1 Cabling

The instrument should be connected to AC power immediately to quickly lower warmup drift to a reasonable level. Be sure to adjust the 115/230 volt switch before plugging the unit in.

The Model 796 is ready for use except for input cabling.

1. The input connections are made at BNC type connectors on the front panel. Option N moves the connectors to the rear panel for neater permanent rack installation.
2. The data output connector supplies data, control, functions, and power to external units. See table 3.2.3 for the arrangement of the connector. A variety of optional cables make the 796 immediately compatible with a number of printers of different manufacturers. For further information, see the option table.
3. On equipment fitted with option J (remote control) there is a remote control connector on the rear panel. See table 3.2.4 for the connector and pin allocations.

4. The Reset connector is a BNC fitting on the rear panel. This input requires a pulse of at least 1 μs duration and ground to -4V level. It is effective only in the EXT RESET mode, as selected by the Display Time control.
5. The Test pulse connector, a BNC on the rear panel, provides a fast-rise pulse 30 μs after any reset. This pulse is positive and at least 20V high into 50Ω. It is used to trigger a calibrator or other external equipment.
6. The Start Enable connector functions only when the Start Enable switch is in the EXT position. In that case, the unit is prohibited from starting a time measurement until the BNC connector on the rear panel receives a negative trigger pulse of magnitude -3V or more and duration at least 1 μs.
7. The trigger monitor provides a 5 ns, 0.5V pulse every time the discriminator produces a Start or a Stop pulse. This is useful for monitoring the triggering on an oscilloscope. It is best done with a fast dual-beam scope that can display the input trace and the discriminator output simultaneously.
8. Finally, the 1 MHz oscillator normally provides an output for external monitoring or calibration of the internal 1 MHz standard. When the oscillator switch on the rear panel is in the EXT IN position, however, this fitting becomes an input connector for an external frequency standard. Be careful, of course, not to connect an external frequency source to this connector when the oscillator switch is in the INT MON position. This could have serious consequences for both oscillators.

CHAPTER 3

OPERATION

CHAPTER 3

OPERATION

3.1 GENERAL

Operation of the Model 796 Time Interval Counter is straightforward. All of the controls are clearly labeled and perform definitive and independent functions. This section includes a detailed list of the units controls and their functions, a set of simplified operating instructions, and comments on a few possible operating problems and their solutions.

3.2 CONTROLS AND CONNECTORS

Table 3.2.1 lists the controls and connectors on the front panel of the 796. Table 3.2.2 lists the rear panel switches and connectors. Tables 3.2.3 and 3.2.4 list the connections to the data and the optional remote control connectors respectively.

3.3 SIMPLIFIED OPERATING INSTRUCTIONS

This section includes brief discussions of set up procedures for each of the three modes. The instructions are intended to be more helpful than definitive.

3.3.1 TIM Mode

Let the instrument warm up for at least 4 hours. Set the polarity and slope controls for both channels. Usually, both channels should be set to the leading edge of their pulses. Set the multipliers and trigger level controls correctly. Put the display mode in DIRECT and press Reset. (Display Time at EXT. Reset, Start enable at INT.) Apply Start and Stop inputs as required by your measurement. If the displays assume a reasonable reading, everything is fine. If they stay at zero, the instrument is not starting properly. Check the A Channel controls. If they are set correctly, check the connection of the A input cable and see that whatever is supposed to start the counter is working properly. If the counter shows a steady blur, with the least significant two digits fixed at zero, the counter is not getting a stop signal. Check the B Input controls and cablery.

If you are unsure of the level of the input signal, connect only the start input cable and set the trigger level at a point you know to be too high. Cause the input pulse to be

repeated as quickly as possible. Turn the level control down gradually until the indicators blur. The instrument must be in the DIRECT mode. If you are interested in measuring from the 50% point of the input, turn the A Multiplier down one step. For 10% triggering, turn the multiplier down three steps, and the level control down by one-fifth of its reading. Then connect the B channel, pulse it as quickly as possible, turn its level control down until the instrument stops, and if necessary, adjust the multiplier and trigger level. Then reset the counter manually and cause a set of inputs. See that the time reading is sensible.

After the trigger controls have been set and checked, the Display Mode, Reset, and Start enable conditions can be set for maximum convenience.

3.3.1 Period and Width Modes.

Let the instrument warm up for at least 4 hours. Set Display mode to DIRECT, Display time to EXT RESET, and START ENABLE to INT. Set the trigger level, polarity and slope controls. Apply the input. Press the Reset button and see whether the display reads sensibly. If not, check the control settings and the input. Turn the trigger level down until a reading occurs.

3.4 PROBLEMS

If the instrument adamantly refuses to read correctly, check the following:

1. The START ENABLE switch. If it is in the EXT position, ensure that you are supplying a start command.
2. The Display mode switch. If it is in the STORE position, and the instrument has somehow hung up, the indicators will never show it.
3. The input connections. Make sure that they are tight, and that the cables are not defective.

If possible, monitor the TRIG MON jack and the input simultaneously on a fast oscilloscope. See that the trigger pulses occur when you want them, and that you are not triggering on spurious noise or on the wrong slope. Bear in mind that the observed pulses are delayed somewhat in the discriminator and that the oscilloscope cables introduce delays of their own - - the TRIG MON can give only a rough idea of what the discriminator is doing.

4. If ever in doubt, manually reset the instrument and try it again. If the instrument still fails to read correctly, make a last quick check for silly mistakes and refer it to the person or department responsible for its calibration and maintenance. Do not adjust the Null pot unless you have the proper equipment. Above all, do not open the cabinet and start moving trimmers.

TABLE 3.2.1

MODEL 796 TIME INTERVAL COUNTER

FRONT PANEL CONTROLS

CONTROL	FUNCTION
RESET	This button sets all the unit's counters and control logic to zero. It is used to set the initial state of the unit when the power is turned on, to manually clear the unit after a measurement to make way for a subsequent one, and to reinitialize the unit should it somehow "hang up".
NULL	This trimmer pot adjusts the fine timing of the unit. It should not need daily trimming. Refer to the chapter on calibration.
DISPLAY MODE	This is a three position rotary switch.
PWR OFF	In this position of Display Mode, the AC power to all the circuits of the units is disconnected. The stabilizing ovens, however, of the VCO's and the 1 MHz oscillator stay on.
DIRECT	In this mode, the display tubes follow the DCU's directly. Thus the counting action of the unit is visible on the display.
STORED	Here the display retains one reading until the unit has finished making another. This mode is most useful when making repetitive measurements.
DISPLAY TIME	This control includes a potentiometer ganged with a switch. The potentiometer adjusts the time between the completion of a time measurement and the instrument's automatic reset - - the display time - - over a range of from approximately 0.1 s to 5 s or longer. When the potentiometer is rotated full CW, the switch is engaged and the instrument is in the EXT RESET mode.
MODE SWITCH	This is a 3 or 4 position rotary switch. It selects the input mode of the instrument. The 4th position exists only when option J, remote control, is installed.

TIM (A-B)	In this mode, the instrument measures the time intervals between the inputs at the A and B input connectors. The slope, trigger level and trigger polarity of both inputs are independently adjustable. The instrument can measure time from -10 ns to the maximum capacity of its counters.
PERIOD (A)	In this mode, the instrument measures the time between sequential similar slopes and levels of the A input. Only the input controls associated with the A input are active. Interlock logic is necessary in this mode to prevent spurious zero readings. This limits the range of the instrument to 50 ns and above.
WIDTH (A)	Here, the instrument measures the time between two complementary slopes of the A input. The trigger level is the same on both slopes. Due to the finite recovery time of the A input trigger, the minimum acceptable pulse width in this mode is 20 ns.
REMOTE (option)	When option J is installed, this position allows remote programming of mode, trigger level, and slope.
A INPUT Connector	This BNC connector accepts the start input to the counter.
A (START) TRIGGER LEVEL	There are two controls that adjust the A trigger level. They are the A Level control and the A multiplier.
A LEVEL	This potentiometer adjusts the critical level of the A input trigger from 0.1 to 1 times attenuator setting.
A MULTIPLIER	The A multiplier attenuates the A input signal, and thus multiplies the effective trigger level, by a factor of 1, 2, 4, 8, 16, 32, 64, or 128. The trigger level is variable from 0.1V to 128V in eight widely overlapping ranges.
A (START) POLARITY	The A polarity switch selects a positive or negative trigger voltage for the A trigger. In combination with the trigger level controls it allows selection of any trigger level from 0.1V to ±128V.
A (START) SLOPE	This control selects A input triggering on either the positive or the negative slope of a pulse. In combination with the three previous controls, this allows triggering almost anywhere on an input waveform.

B (STOP) TRIGGER LEVEL, SLOPE, POLARITY, INPUT Connector

The controls associated with the B channel are directly analogous to the similar controls on the A channel. They are different only in that they affect the stop channel of the unit. Their settings are meaningless except in the TIM mode.

PROBE POWER Connectors (option)

When option L is installed, two power connectors for Tektronix type P6045 source-follower probes are installed. These probes allow high-impedance measurement of fast rise times.

TABLE 3.2.2

MODEL 796 TIME INTERVAL COUNTER

REAR PANEL CONTROLS

START ENABLE	Normally this recessed slide switch is in the INT position. Then the 796 counter will be started by the first legal start input as determined by the trigger controls. In the EXT. position, the switch inhibits starting until a Start Enable command of proper level has appeared at the proper connector.
START ENABLE Connector	This is a type BNC connector. In the EXT START ENABLE mode (see above) this input will enable starting after it has received a negative input pulse (ground to -3 to -10 volts, duration 1 μs or longer).
1 MHz OSC Switch	In its normal INT MON position this switch connects the 796's stabilizer circuitry to the unit's internal oscillator. In its EXT IN position, it causes the stabilizer to be operated from an external 1 MHz source.
1 MHz OSC Connector	When the 1 MHz OSC switch is in the INT MON position, this BNC connector is an output, for convenient observation of the internal 1 MHz oscillator. In the EXT IN mode, the connector becomes an input for an external 1 MHz source.
115/230 Vac	This switch connects the transformer primaries within the unit in series or parallel to enable operation from either 115 or 230 Vac lines. Move only while AC line cord is unplugged.
LINE CORD	A permanently attached six foot cord with a standard three-wire AC connector supplies AC power to the unit. For 230 Vac use, the plug will probably have to be changed or an adaptor used, in any case the counter chassis should be grounded, both for safety and for noise immunity.
TRIG MON Connector	This BNC connector produces an 0.5V pulse about 10 ns wide every time the discriminator produces a start or a stop pulse. This output is useful to check the triggering functions of the unit.

EXT RESET Connector

When the unit is in its EXT RESET mode, selected by the front panel Display Time Control, the unit can be reset by a negative pulse (ground to -4 to -10 volts, 1 μs or longer) applied to this BNC connector.

TEST PULSE Connector

This connector displays a +20V or more positive pulse 30 μs after any reset input. It is intended mainly for use with the Eldorado calibrator, but may be used with other equipment.

DATA OUTPUT Connector

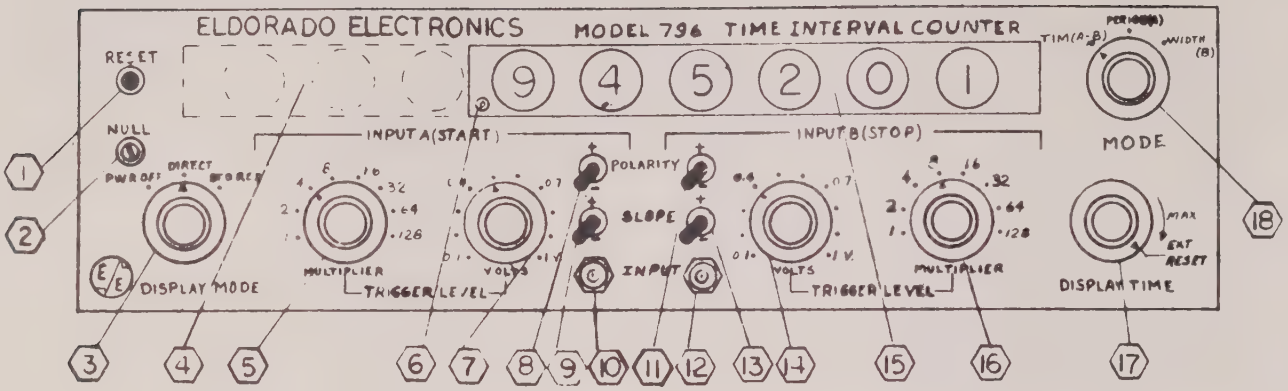
This is an Amphenol in-line connector, type 57-40500. Its mating fitting (not supplied) is Amphenol type 57-30500. Its wiring is listed in table 2.3.3.

REMOTE CONTROL Connector (option)

When option J is installed, this connector provides for remote programming of mode, trigger level and polarity, and slope. It is an Amphenol 57-40240, and its connections are listed in table 2.3.4. The mating fitting is supplied.

INPUT Connectors (option)

When option N is installed, the A and B input connectors are on the back instead of the front panel.



1 Manual Reset Button
2 Null Adjust
3 Display Mode Switch
4 9 Digit Display Indicators
5 Input A Trigger Level Multiplier
6 Overflow Lamp
7 Input A Trigger Level Adjust
8 Input A Polarity Switch
9 Input A Slope Switch
10 Input A Connector
11 Input B Polarity Switch
12 Input B Connector
13 Input B Slope Switch
14 Input B Trigger Level Adjust
15 Display Indicators
16 Input B Trigger Level Multiplier
17 Display Time Control
18 Mode Switch
19 Test Pulse Output
20 External Reset Input
21 INT/EXT Start Enable Switch
22 Start Enable Input
23 INT EXT Oscillator Switch
24 MON/IN Oscillator Connector
25 Trigger Monitor Output
26 Remote Control 36 Pin Connector (Option J only)
27 Data Output Connector
28 Line Fuse
29 115/230 Vac Switch
30 Power Cord
31 Air Filter

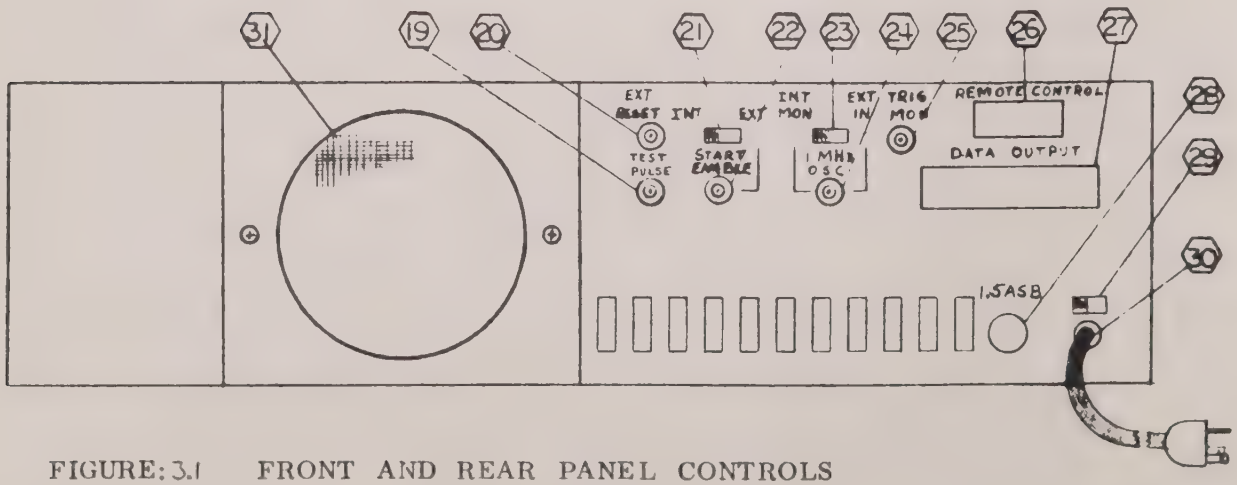


FIGURE: 3.1 FRONT AND REAR PANEL CONTROLS

TABLE 3.2.3

DATA OUTPUT CONNECTOR J1 WIRING

PIN #	FUNCTION	PIN #	FUNCTION
1	10^0_0 1 bit	26	10^0_0 4 bit
2	10^1_0 2 bit	27	10^1_0 8 bit
3	10^1_1 1 bit	28	10^1_1 4 bit
4	10^2_2 2 bit	29	10^2_2 8 bit
5	10^2_2 1 bit	30	10^2_2 4 bit
6	10^3_3 2 bit	31	10^3_3 8 bit
7	10^3_3 1 bit	32	10^3_3 4 bit
8	10^4_4 2 bit	33	10^4_4 8 bit
9	10^4_4 1 bit	34	10^4_4 4 bit
10	10^5_5 2 bit	35	10^5_5 8 bit
11	10^5_5 1 bit	36	10^5_5 4 bit
12	10^6_6 2 bit	37	10^6_6 8 bit
13	10^6_6 1 bit	38	10^6_6 4 bit
14	10^7_7 2 bit	39	10^7_7 8 bit
15	10^7_7 1 bit	40	10^7_7 4 bit
16	10^8_8 2 bit	41	10^8_8 8 bit
17	10^8_8 1 bit	42	10^8_8 4 bit
18	10^8 2 bit	43	10^8 8 bit
19	Overflow	44	-12Vdc
20	Negative count	45	-12Vdc
21	Reset	46	-6Vdc
22	Inhibit	47	-30Vdc
23	+6 Vdc	48	- Print Command
24	- Ref (-9V)	49	NC
25	Ground	50	Ground

NOTES:

1. 10^0 is the least significant digit and appears as the digit farthest to the right.
2. Pin 24 (-9 volt reference) is from a resistor network consisting of 390 ohms in series with -12 volts with 1.8k ohms to ground.
3. Negative print command is a negative step from nominal 0 to -12Vdc at end of count cycle. Fall time is approximately 1 μs. The duration depends on display time and ranges from 100 ms minimum to 10 seconds maximum. Source impedance is approximately 1k ohms.
4. Reset is positive pulse from -6V to +6V 50 μs wide. Internal impedance nominal 50 ohms.
5. Inhibit accepted is 0V if supplied from <1k ohms resistance, to 30V at up to 30k ohms resistance. For non-inhibit reset, requires release level of 0V to -6V if from >20k ohms resistance, or -6V to -30V from any source impedance.
6. Output connector is Amphenol jack 57-40500. Mating connector is Amphenol 57-30500.
7. Unused digits wired to Print Zero.

TABLE 3.2.4

REMOTE CONTROL CONNECTOR WIRING

PIN NO.	FUNCTION	PIN NO.	FUNCTION
1	TIM Mode note 1	11	Start Trigger ground note 3
2	Period Mode note 1	12	Start Trigger reference note 3
3	Width Mode note 1	13	Ground
4	Stop Slope note 2	14	Stop Trigger reference note 3
5	Stop Polarity note 3	15	Stop Trigger ground note 3
6	Start Slope note 2	16	Stop Trigger level note 3
7	Start Polarity note 2	17	+6Vdc
8-9	NC	18	-6Vdc
10	Start Trigger level note 3	19-24	NC

NOTES:

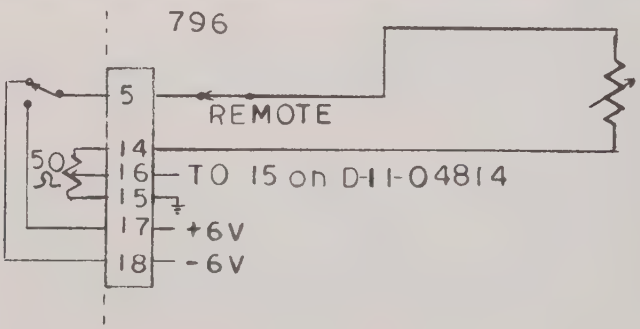
1. To select Mode, apply +4 to +6 Vdc to desired mode terminal, return other mode terminals to a -4 to +0.5 Vdc source or an open circuit. The input impedance of each mode, polarity, and slope selection input is about 3k.

2 + Stop Slope Selection, apply +4 to +6 Vdc to pin 4.
- Stop Slope Selection, apply -4 to +0.5 Vdc to pin 4.
+ Start Slope Selection, apply +4 to +6 Vdc to pin 6.
- Start Slope Selection, apply -4 to +0.5 Vdc to pin 6.

3. Stop Polarity and Trigger Level
The voltage polarity and level applied to pin 16 selects the stop trigger level. Negative voltage selects negative polarity, positive voltage selects positive polarity; trigger point will be at the level applied to pin 16 (maximum 3 volts). See alternate procedure 3a below.

Start Polarity and Trigger Level
The voltage polarity and level applied to pin 10 selects the start trigger level. Negative voltage selects negative polarity, positive voltage selects positive polarity; trigger point will be at the level applied to pin 10 (maximum 3 volts). See alternate procedure 3a below.

3a. To duplicate front panel controls
Stop Polarity and Trigger Level
1. Place 50 ohm potentiometer across pins 14 and 15 return the wiper to pin 16.
2. Connect a SPDT switch with common to pin 5 and one terminal to pin 17 for +6 volts reference and the other terminal to pin 18 for -6 volts reference.



Start Polarity and Trigger Level
1. Place 50 ohm potentiometer across pins 11 and 12, return wiper to pin 10.
2. Connect a SPDT switch with common to pin 7 and one terminal to pin 17 for +6 volts reference and the other terminal to pin 18 for -6 volts reference.

4. Remote connector is an Amphenol 57-40240, requires mating connector type 57-30240.

CHAPTER 4

THEORY OF OPERATION

CHAPTER 4

THEORY OF OPERATION

SECTION I

4.1 INTRODUCTION

4.1.1 SCOPE

This chapter contains three sections, numbered 4.1, 4.2, and 4.3. This first section contains a general introduction to the chapter and a discussion of the principles of operation of the Eldorado Electronics Model 796 Time Interval Counter. It fully explains the unique logic that enables the Model 796 to measure intervals of time to within one nanosecond without using gigahertz counting circuitry and without the ± one count error usually associated with digital counters.

Section 4.2, GENERAL THEORY OF OPERATION, discusses the operation of the counter from a block diagram point of view. The function of each amplifier, gate, and flip-flop, are explained separately. A thorough reading of section 4.2 should give the reader sufficient understanding of the Model 796 to enable him to use the instrument thoughtfully and to localize any trouble that may develop.

Section 4.3, SPECIFIC THEORY OF OPERATION, parallels section 4.2 but discusses each circuit in greater detail. Each logical function is associated with its particular components. Every component in the unit is not specifically discussed, but all unusual circuits are fully explained. This section is most useful as a reference appendix to section 4.2.

4.1.2 THE MODEL 796 TIME INTERVAL COUNTER

The Eldorado Electronics Model 796 Time Interval Counter is at this writing unique in the industry. It is the only instrument extant (except for the now discontinued Eldorado Model 793) which is capable of measuring time intervals from one nanosecond to 999, 999, 999 ns without range switching with accuracy of ±1.5 ns over the entire range of the instrument.

The Model 796 includes highly versatile input circuitry which allows the measurement of time intervals, pulse widths, and the periods of repetitive signals over a wide range of input voltages. The unit is capable of triggering on low amplitude cable reflections or of clocking the 115Vac line by simple adjustment of front panel controls.

The instrument includes a "Nixie" type time display, data and control outputs to external equipment, and a versatile control system that allows it to be started and reset either by its own internal logic or by other instrumentation.

Normally, a counter with a resolution of 1 ns would include a precision 1 GHz oscillator, a counter capable of operating at 1 GHz, and a very fast gate to enable the counter during the time interval to be measured. Such a counter could conceivably be built with today's technology. However, gigahertz logic is fussy and expensive. The delay times in such a circuit would be extremely critical and difficult to "tune out" to obtain accurate measurements. As versatile an input circuit as the 796's would be well-nigh impossible. Also the counter would still be beset with the ± one count quantizing error associated with asynchronous counters, so its resolution would be only 2 ns.

The Model 796 counts 100 ns units of time at the relatively liesurely rate of 10 MHz and measures the remaining 99 ns or fewer by vernier interpolation. The slower logic allows signals to be delayed conveniently, lowers cost of components and incidentally allows the quantizing error to be gated out. Thus accurate measurements in the nanosecond range are possible with high reliability and at less than exorbitant cost.

It would be helpful now to refer to the Simplified Block Diagram.

The Model 796 has two signal inputs, A and B. In the TIM (A-B) mode, the 796 is started by a signal at the A input and stopped by one at the B input. In the WIDTH (A) and PERIOD (A) modes, the instrument measures the time between opposite slopes of pulses and similar slopes of periodic functions applied to the A input respectively.

The A and B inputs are processed by the input attenuators and discriminator circuits and used to derive START and STOP levels. The instrument measures the time difference between the transitions of these levels.

The START level causes a 10 MHz oscillator called the Start Clock to turn on. The gating circuitry of this oscillator is so designed that a fast-rise signal like START will start the clock with accurately known phase - - if, for example, two similarly-tuned oscillators were started with one signal, their outputs would be exactly in phase.

The output of the Start Clock is a 10 MHz square wave, which is fed through the Add One logic and counted by the DCU's (Decade Counting Units), which represent increments of

100 ns or more. When the Stop signal arrives, the Add One logic stops the count to the main DCU's. Finally, the Add One logic decides whether it has made a quantizing error and, if so, corrects it. This logic will be discussed more fully later.

Meanwhile, STOP turns on the Stop Clock, an oscillator similar to the Start Oscillator but set to 10.1 MHz. Since the Stop Clock has the same startup circuitry as the Start Clock, it starts out of phase with the Start Clock by a time difference equal to the two least significant digits of the time between the START and STOP signals. For example, assume that the interval being measured is 5432 ns. In this period, the Start Clock makes 54.32 complete cycles. The Stop Clock starts at 0.32 cycles, or 32 ns, out of phase with the Start Clock. Now, since the period of the Stop Clock is only about 99 ns, it "catches up" in phase with the Start Clock by 1 ns per cycle. In fact, in 32 cycles, it will catch up completely with the Start Clock and be momentarily in phase with it.

The positive slopes of both oscillators are differentiated and compared by the Picosecond Coincidence Gate. The gate produces a true output when the signals are simultaneous to within 500 ps. The gate has a resolution of approximately 1 ps.

The output of the Stop Clock is counted by the "interpolation counter", the two least significant digits of the instrument's accumulator, until the coincidence gate produces a true output. Then all counting stops.

In the example (5432 ns) the following sequence takes place:

1. START occurs and turns on the 10 MHz Start Oscillator. This oscillator is counted by the main DCU's.
2. Stop occurs 5432 ns later. The main counter stops counting at 54 (5400 ns). The Stop Oscillator starts, and the interpolation counter counts its output.
3. 3168 ns (32 x 99) later, the coincidence gate senses zero phase difference between the oscillators. All counting stops. The interpolation counter now indicates 32. The accumulator now reads, correctly, 5432 ns. This counting principle is directly analogous to that of a machinist's vernier caliper. See Figure 4.1.1.

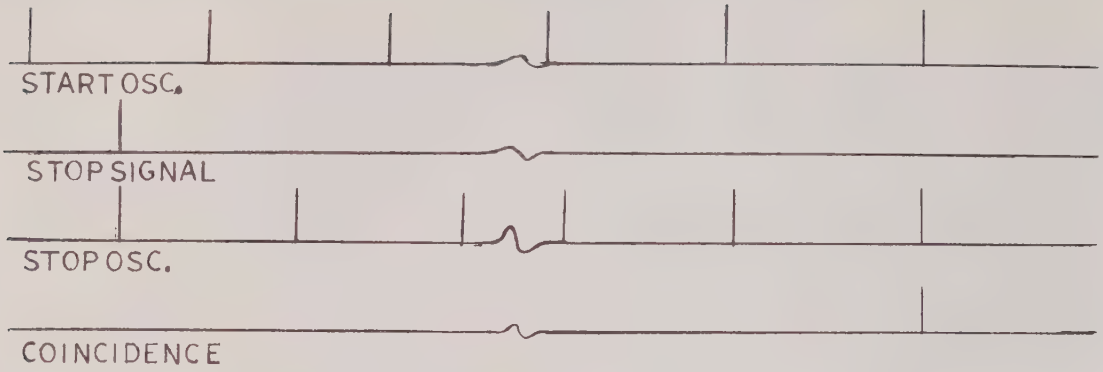


Figure 4.1.1 Vernier Principle

Sometime later, the instrument is reset, either by its internal Display Timer, by a RESET command from some external piece of equipment, or by manual actuation of the Reset button on the front panel. Any reset stops both oscillators, returns both counters to zero, and resets the control logic of the instrument to its original state. The displays, however, can be set to retain their old reading until a new measurement is completed.

While long time intervals (over 8 μs) are being measured, the Start Oscillator is referenced to a precision 1 MHz crystal oscillator and a stabilizer circuit. Very simply, the stabilizer derives a 10 MHz signal of approximately known phase relationship with the Start Oscillator from the 1 MHz standard. It then compares and later holds constant the phase difference between the two signals. Several different standard oscillators are available, with increasing stabilities.

In most digital counters, a constantly-running oscillator is gated into a count chain by a signal derived from the input signals. If the gating occurs at or near the zero crossing of the oscillator, it is possible for a spurious pulse to be generated and counted, or for a true pulse to be so shortened that the counter ignores it. Thus the measurement made by any such counter is accurate to plus or minus one count, regardless of the accuracy of the internal oscillator and the quality of the gate circuitry. The Model 796 has TWO counters, and thus two chances for such an ambiguity, one in the 1 ns decade and one in the 100 ns decade. The logic of the 796 disallows such errors in both places.

The possibility of an error in the interpolation counter can be dismissed quickly. The STOP signal does not gate an oscillator output - - it starts an oscillator. Since the first cycle of the oscillator is known to be "good" no error can occur at the start of the count.

The interpolation counter is gated off by the Coincidence Pulse - - a signal derived from the Stop Oscillator itself. Thus each cycle of the stop clock is definitively counted or not counted - no partial cycles can be applied to the counter and no error can occur.

We now come to the more complex problem of the main counter. The main counter is gated on as is the interpolation counter, so no error can exist there. But it can be gated off at any time during its cycle. An error in this counter would mean a 100 ns error in the output reading, which would render the 1 ns resolution of the instrument useless. Thus the Add One logic is built into the unit to eliminate this error. Simply, the Add One logic delays the count of the main counter to make a + one count error impossible. Then it stores information corresponding to the state of the Start Oscillator at STOP time. Later, when the interpolation count has finished, this information is loaded into the main counter as necessary.

The Add One action can be best understood by considering the timing as a series of "frames" of 100 ns, synchronized with the input. The times in this frame when the counter is triggered are critical. Refer to figure 4.2 below and to the Timing Diagram.

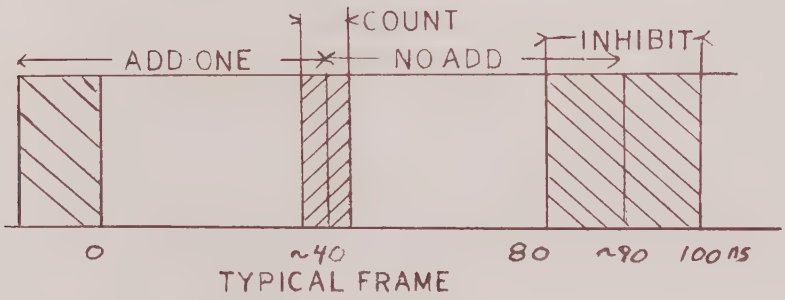


Figure 4.1.2 Add One Timing

The output of the Start Oscillator is stored in a flip-flop called READOUT. It is important to note that READOUT follows the Start Oscillator - - it does not perform a divide-by-two function. When the Start Oscillator changes state, READOUT follows it directly. The 100 ns DCU is driven by the output of the READOUT flip-flop. When STOP time arrives, the inputs to the READOUT flip-flop are inhibited.

The count is so timed that the main counter does not receive its Nth count until well after N hundreds of nanoseconds have passed. This eliminates the possibility of a 100 ns error in the positive direction. It greatly increases the probability of a 100 ns negative error.

In fact, the count occurs at about 100 (N) + 40 ns. The oscillator resets at about 100 (N) + 90 ns. Thus if the STOP signal arrives at between about 40 and 100 ns, the count will be correct, if, however, the STOP appears at somewhere between 0 and about 40 ns, a count will be missed. The bounds of the error region are within 5 ns or so of 40 ns. Therefore, the READOUT flip-flop is interrogated at the time of the coincidence pulse. If it is in its reset state (90-40 ns) an extra count is fed to the main DCU's. Note that this would add a superfluous count to the DCU's if the STOP signal had appeared between about 90 and 99 ns. Therefore, the interrogation is inhibited by an output of the interpolator counter in the region from 80 to 99 ns. The interpolator count, remember, is definitively accurate to the nearest nanosecond. If it has reached 100 (or 00) the main counter has definitely missed a count. If it has reached only 99, a cycle definitely has not been missed. Thus the timing error is disallowed and the Model 796 always reads as accurately as its internal standard oscillator will allow.

SECTION 2

4.2 GENERAL THEORY OF OPERATION

4.2.1 Introduction

This section describes the operation of the Eldorado Electronics Model 796 Time Interval Counter in stage-by-stage detail. It does not discuss circuit details or logic levels, but it mentions every important signal and fully explains the unit's timing.

The Model 796 measures the time interval between two events to an accuracy of ±0.5 nanoseconds ± a function of the stability of its internal oscillator. It contains circuitry that allows it to accept a wide range of input signals, disallows the ± 1 count error usually associated with digital counters, and makes it compatible with external equipment.

It is possible to build a 1 nanosecond direct counter, but such an instrument would be fussy and expensive. The Model 796 makes its time measurements by vernier interpolation, which is less straightforward but more reliable and economical than direct counting.

The first event starts a 10 MHz clock. The clock is so designed to start exactly at the beginning of a cycle - at 0° phase angle to its start signal. This clock drives a digital counter which accumulates 100 ns increments of time.

The second event stops the count to the 100 ns register and starts a 10.1 MHz clock, again at a 0° phase angle to its start. This clock produces a series of pulses 99 ns apart which are counted by a two decade counter representing units and tens of nanoseconds. When the 10.1 MHz clock becomes exactly in phase with the 10 MHz clock for an instant, all counting stops.

The registers contain a representation of the time interval between the two events in question, accurate to the nearest nanosecond. The method of measuring nanoseconds is directly analogous to a machinist's vernier caliper.

The data in the registers is visible on a row of neon display tubes on the front panel and is also available at a connector on the rear panel. The instrument resets itself (or can be externally reset) and prepares itself to make a new measurement.

The block diagram (D-10-04935) in Chapter 7 will make the following explanations more comprehensible.

4.2.2 Input Attenuators

The input attenuators are capable of attenuating both signal inputs by factors of 2, 4, 8, 16, 32, 64, or 128. Both attenuators are adjustable from the front panel. Each has an input impedance of 50 Ω.

4.2.3 Discriminator

The discriminator derives control commands to the counter circuitry from the attenuator input signals. Its inputs are the attenuated A and B signal inputs. The A and B Trigger Level and Polarity controls, the Start and Stop Slope switches, the Mode switch, the Null control, and a DISABLE signal from the Control Logic. Its outputs are START signals to the Start Oscillator, the Stabilizer, the Add One logic, and STOP signals to the Stop Oscillator and the Add One logic.

The discriminator contains two triggers, a set of mode gates, two control flip-flops, START and STOP, a 50 ns delay used in the PERIOD mode, and several output buffers. Refer to the discriminator schematic and the discriminator block diagram, figure 4.2.1.

a. There is a high-speed tunnel-diode trigger for each of the two inputs. The A trigger has two outputs, A-plus and A-minus. A pulse appears at the A-plus output when the attenuated A input voltage increases past a certain trigger level set by the A Trigger Level and A Polarity controls. A pulse appears on the A-minus line when the voltage drops back past the same level. Note that the A-plus pulse may appear while an A input voltage is negative, or the A-minus while the input is positive. The steering of the pulse is dependent not on the level of the trigger input but on its slope. The B trigger produces a pulse when the B input voltage passes a certain level set by the B Trigger Level and B Polarity controls. The Stop Slope switch determines whether the pulse will appear on the positive or negative input slope.

The trigger levels of both triggers are adjustable from 50 mV to 1V and from -50 mV to -1V by the respective Trigger Level and Polarity controls. In combination with the attenuators, the triggers can be set to any point within the range of ±50 mV to ±128V. The triggers are protected against overvoltage so long as their dissipation rating of 0.25 watts into 50Ω is not exceeded.

b. The A-plus, A-minus, and B pulses are steered to the START and STOP flip-flops by the Mode and Start Slope switches acting through a set of gates.

When the mode switch is in the TIM (A-B) position, the A-plus or A-minus pulse is steered to the START flip-flop. The pulse is selected by the Start Slope switch. The STOP flip-flop is pulsed through its 36 ns delay by the B trigger.

In the PERIOD (A) mode, both the Start and the Stop flip-flops are pulsed simultaneously (ignoring the stop delay) by either the A-plus or the A-minus pulse.

In the WIDTH (A) mode, the START flip-flop is pulsed by one of the "A" pulses and the STOP flip-flop by the other. The START pulse is selected by the Start Slope control.

In the PERIOD (A) and WIDTH (A) modes, the B Trigger Level, B Polarity, B Attenuator, and Stop Slope controls are disabled.

A pulse appears at the TRIG MON connector on the rear panel whenever either a Start or a Stop pulse is generated.

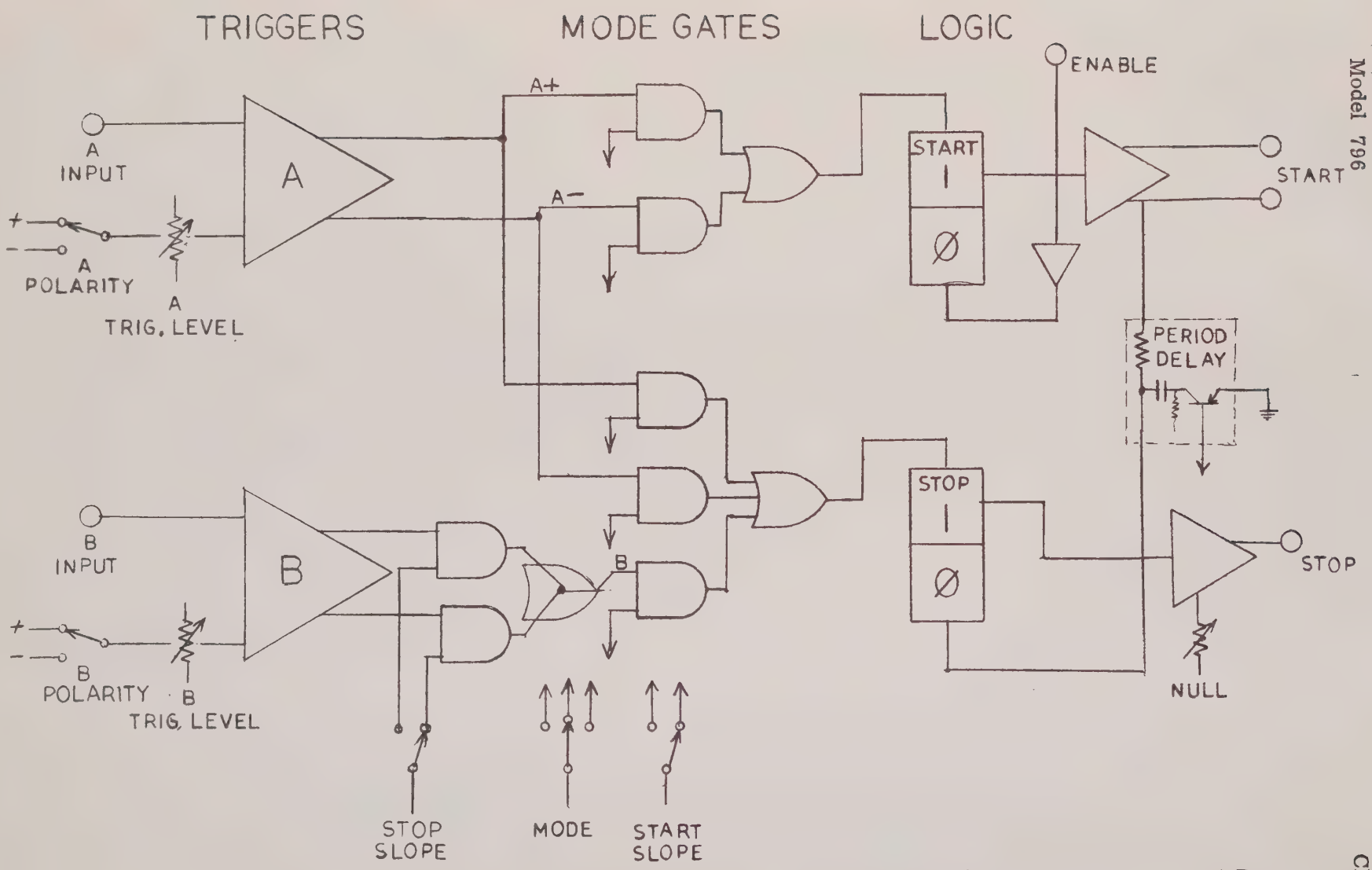
c. The discriminator includes two high-speed tunnel-diode flip-flops, called START and STOP. Both are reset to the "0" state before the start of a measurement cycle.

In all modes, any START pulse sets the START flip-flop immediately to "1".

In all modes, STOP pulse is delayed by 36 ns and tries to set the STOP flip-flop to "1". The STOP flip-flop is disabled, that is, not allowed to be set, as long as the START flip-flop is in the "0" state.

In the TIM (A-B) and WIDTH (A) modes, the STOP flip-flop is enabled immediately after the START flip-flop is set (gate delays slow "immediately" to 20 ns or so). Thus because of its 36 ns delay, STOP can be set by a signal that arrives up to 10 ns before the START signal. Thus the Model 796 can measure "negative time" down to about -10 ns.

In the PERIOD (A) mode, STOP is not enabled until some 50 ns after START. Thus the simultaneous START and STOP pulses in this mode will not confuse the logic -- the first



SIMPLIFIED BLOCK DIAGRAM
MODEL 796 DISCRIMINATOR

FIG. 4.2.1

pulse will set START and the second STOP. Unfortunately, this delay prevents the measurement of periods below 50 ns. "Negative time" is of course meaningless in this mode.

Both flip-flops are cleared to "0" by the ENABLE signal from the Control Logic. This signal appears at the end of each measuring cycle and is discussed in section 4.2.11.

d. The START flip-flop output is buffered, delayed 36 ns by a passive cable delay, and fed to the gate input of the Start Oscillator; delayed by 15 ns and fed to the Stabilizer gate; and fed undelayed to the Stabilizer memory gate and the Add One logic. When it reaches the Add One logic it is renamed 1st PULSE INHIBIT.

The output of the STOP flip-flop is buffered, and fed to the Stop Oscillator gate input and the Add One logic. The zero-crossing of its output, and thus its timing, is adjustable by the Null potentiometer, a screwdriver-adjust control on the front panel.

4.2.4 Start and Stop Oscillators

The Start and Stop Oscillators are similar Colpitts type Voltage-Controlled-Oscillators. Their output frequencies are trimmable by varicap diodes in their tank circuits. Each oscillator can be switched on and off by its gate input. The oscillators are so designed that on receipt of a gate signal they turn on immediately -- there are no defective cycles at "startup" and the first cycle is complete and in phase with the second. The frequency determining components of the oscillators are enclosed in thermostatically-controlled ovens.

The oscillator outputs are amplified and shaped into complementary pairs of square waves.

The Start Oscillator is set to 10.0 MHz and stabilized to 10.000000 MHz or better by the Stabilizer, which is discussed in the next section. It is turned on by the delayed START command from the discriminator. Its output goes to the main counter through the Add One logic and to the Coincidence Gate.

The Stop Oscillator is set to 10.1 MHz by a potentiometer and is not controlled by any outside frequency standard. It is enabled by the STOP output of the discriminator and is fed to the interpolator counter through the Stop Logic and to the Picosecond Coincidence Gate.

4.2.5 Stabilizer

The stabilizer keeps the Start Oscillator very exactly at 10 MHz. Its circuitry includes a very accurate 1 MHz oscillator, a gated multiplier-divider circuit, a phase memory/comparator circuit, and the associated control circuitry.

a. The 1 MHz frequency standard is a crystal oscillator. Optional oscillators are available in a wide range of frequency tolerances and stabilities. The oscillator is running whenever the unit is plugged in regardless of the position of the Display Mode (power) switch.

When the INT MON - EXT IN switch is in the INT MON position, the output of the 1 MHz oscillator is fed to the multiplier circuit and to the 1 MHz oscillator jack, a BNC connector on the rear panel. In the EXT IN mode, the internal oscillator is disconnected and the 1 MHz oscillator jack is used as an input from an external 1 MHz source.

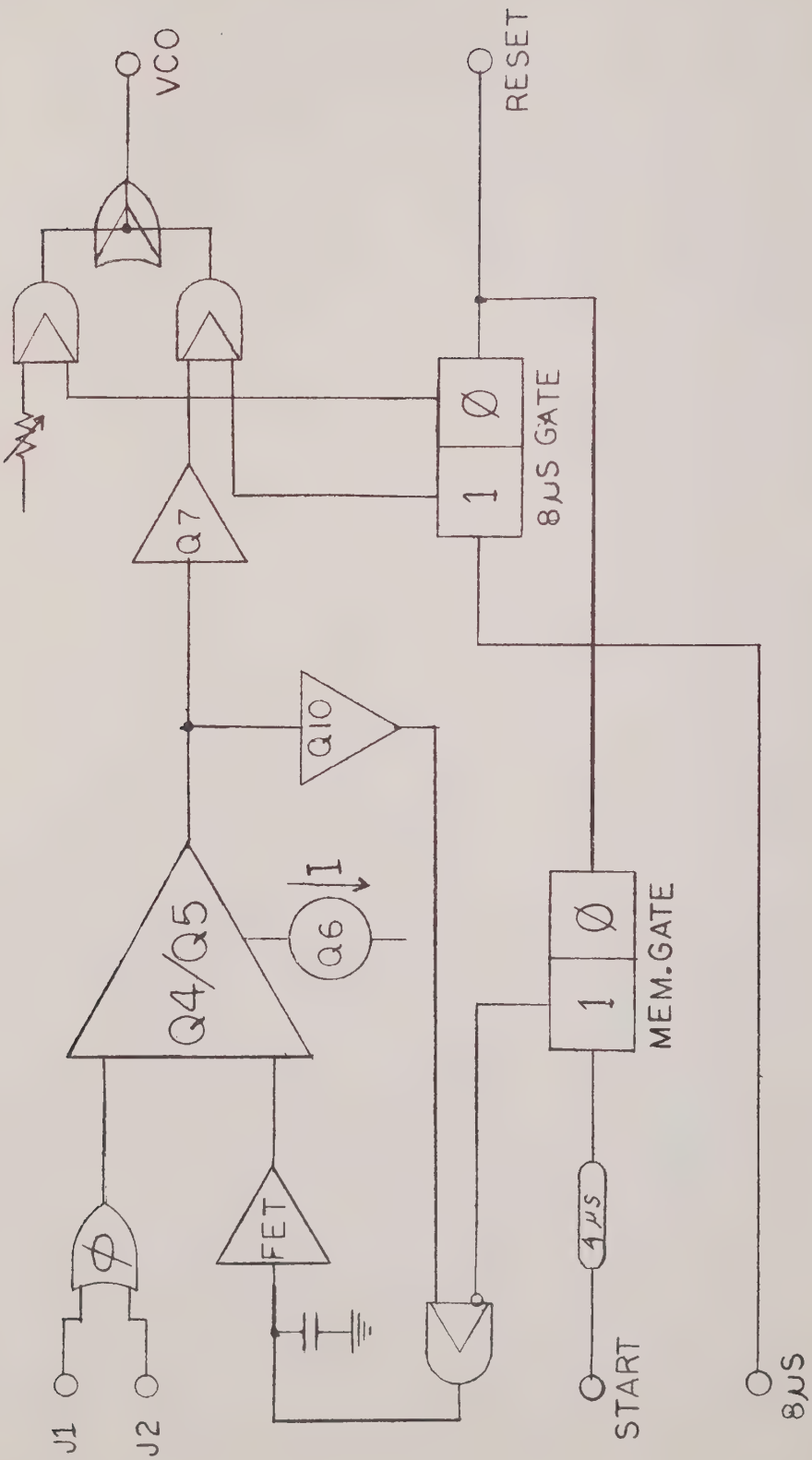
b. The multiplier-divider circuit includes a X80 multiplier and a gated divide-by-eight circuit.

The multiplier is a three-stage class C RF multiplier. Its first stage is tuned to 5 MHz its second to 20 MHz and its third and final multiplier stage to 80 MHz. Thus the first stage multiplies X5 and the next two X4. The output of the multiplier is squared and fed to the gated divider.

The divider includes an AND gate and three flip-flops connected in a divide-by-eight configuration. When the gate receives an enabling START level from the discriminator, the flip-flops start dividing the 80 MHz square wave down to 10 MHz. The gating assures that the 10 MHz wave is in phase with the START oscillator to within a few degrees.

c. The phase detector produces a voltage proportional to the phase difference between this 10 MHz source and the 10 MHz Start Oscillator. This voltage is used to charge a "memory" capacitor. Four microseconds after the discriminator produces a START signal, the detector becomes a comparator. The voltage in the memory capacitor is retained, and is continually compared with new phase information from the oscillators.

The comparator produces a voltage proportional to the difference between the original phase difference between the two oscillators and the phase difference between the oscillators at any later time.



STABILIZER
BLOCK DIAGRAM

FIG 4.2.2

As soon as the 100 ns counter has counted through 8 μs, the output of the comparator is fed to the VCO input of the Start Oscillator. Thus the loop is closed and the Start Oscillator is phase locked to the source.

d. The control circuitry includes a 4 μs delay, a MEMORY GATE flip-flop, and an 8 μs flip-flop.

The MEMORY GATE flip-flop is in the "0" state at the start of a measurement cycle. It is set, after a 4 μs delay, by the START signal from the discriminator. When the MEMORY GATE is set to the "1" state, the phase detector becomes a comparator.

The 8 μs flip-flop is in the "0" state at the start of a memory cycle. It is set to "1" state when the 8000 ns output of the counter first becomes true. When the 8 μs flip-flop is set, the output of the phase comparator is switched to the Start Oscillator VCO input. Otherwise, the VCO input is tied to a potentiometer.

Both flip-flops are cleared to the "0" state by the RESET pulse from the Control Logic. This signal occurs at the end of each measuring cycle and is discussed in section 4.2.11.

4.2.6 Coincidence Detector

The coincidence detector is a high-speed tunnel-diode trigger which produces an output pulse whenever both of its inputs see positive voltage transitions which are simultaneout to within 500 ps.

Its inputs are connected to the start and stop oscillators. Its output goes to the Stop Logic.

4.2.7 Stop Logic

The stop logic allows the output of the stop clock to be counted by the interpolation counter (the two least significant digits of the time reading) until the first coincidence pulse after the counter has accumulated at least 8 ns. If the first coincidence pulse occurs after fewer than eight bits have been counted, the counter runs till the second coincidence pulse arrives, after 100 to 107 counts. The 100th count is spilled from the counter, which reads somewhere between 00 and 07. If the first coincidence pulse occurs after eight or more counts have passed, the counter is stopped between 08 and 99. The stop circuitry includes an OVER 8 flip-flop, a FINAL STOP flip-flop, and associated gating.

The OVER 8 flip-flop is in the "0" state at the start of a measurement cycle. It is set when the 8 ns output of the interpolating DCU's goes true, that is when eight cycles of the Stop Oscillator have passed.

The FINAL STOP flip-flop is in the "0" state at the start of a cycle. It is set to "1" by the first coincidence pulse occurring after the OVER 8 flip-flop has been set. When FINAL STOP is in the "0" state, the output of the Stop Oscillator is fed to the input of the 1 ns DCU. When the FINAL STOP flip-flop is in the "1" state, the input to the 1 ns DCU is inhibited.

Both FINAL STOP and OVER 8 are cleared to "0" by the RESET pulse, explained in section 4.2.11.

4.2.8 Add One Logic

The Add One logic controls the count input to the main counter DCU's, (t x 100 ns and higher) provides a -COUNT indication on measurements of "negative" time, and disallows the ± one count error usually associated with digital counters. It accepts inputs from both oscillators, the discriminator, the 80 ns DCU, and the Control Logic. Included in it are a -COUNT flip-flop, a READOUT flip-flop, the 10 MHz count gate, and associated delays and gates.

The -COUNT flip-flop is in the "0" state at the start of a measurement cycle. It is set if,and only if, the START signal arrives less than about 75 ns before the STOP signal and the count in the interpolation counter is more than 80. Remember that the STOP signal is delayed and that its delay is adjustable by the Null potentiometer. The circuit delays, so add up that the -COUNT flip-flop is set whenever the unit is measuring "negative" time. When -COUNT is set, an indicator on the front panel to the left of the 10 ns neon display tube lights up. -COUNT is cleared at the end of every cycle by the RESET pulse from the Control Logic. Again, this pulse is discussed in section 4.2.11.

The READOUT flip-flop is in the "0" state at the start of a measurement. After the Start Oscillator has started, READOUT follows the negative output of the Start Oscillator. When the Start Oscillator output is low, READOUT is set, and when it is high, READOUT is cleared. Note that READOUT follows the Start Oscillator and does not perform a divide-by-two function.

ADD ONE LOGIC BLOCK DIAGRAM
2 Jan 68 PEG

FIG 4.2.3

The START output of the discriminator is brought to the Add One Logic, renamed FIRST PULSE INHIBIT, and delayed by 110 ns. It is inverted and ANDed with the output of the READOUT flip-flop. The output of this gate is fed to the 100 ns DCU. Thus the 100 ns DCU ignores the first cycle of the Start Oscillator but counts all the subsequent ones.

At the end of a measurement, when FINAL STOP is set, the READOUT flip-flop is interrogated if the contents of the interpolation counter are less than 80 ns. If READOUT is in the "0" state at that time, it is set and another count is entered in the more significant DCU's. Otherwise, nothing happens.

READOUT is cleared to the "0" state by the RESET pulse from the Control Logic if it is not already cleared.

4.2.9 Decade Counters

The 796 contains two sets of decade counters (DCU's). The first is a two-decade register called the Interpolation Counter. Its contents represent the two least significant digits of the measured time interval in units and tens of nanoseconds. It counts the output of the Stop Oscillator in "vernier time". The second is a register of four to seven decades which represent the most significant part of the measured interval, in units of from hundreds of nanoseconds to tenths of a second.

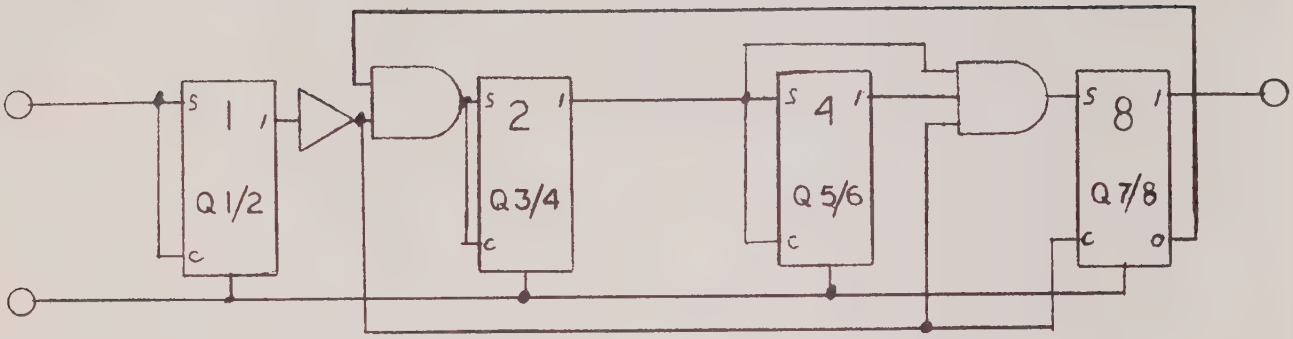
All the DCU's are conventional 1-2-4-8 decade counters. See the truth table and timing diagram, figure 4.2.4.

The 1 ns and 100 ns DCU's may be operated at input frequencies of up to 25 MHz. In this unit they are operated at 10 or 10.1 MHz. The 10 ns and 1000 decades are rated at 2.5 MHz and run at 1 MHz. The remaining decades are rated at 250 kHz and run at 100 kHz or less.

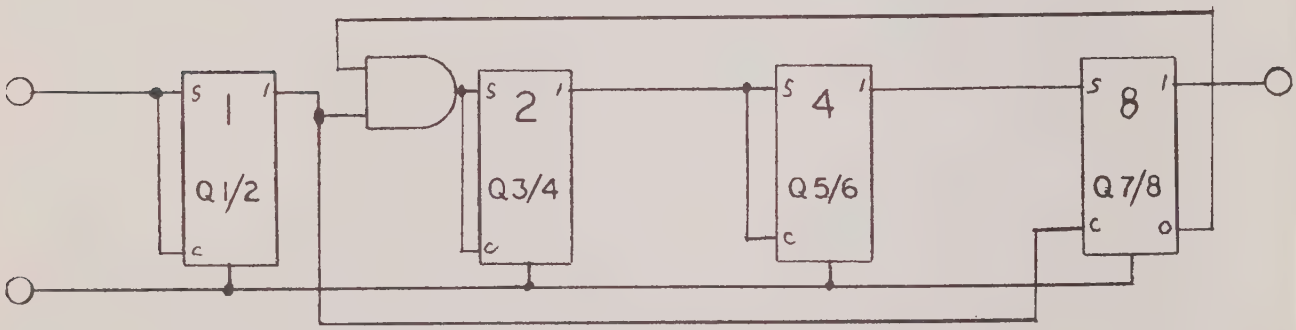
All the counters are reset to "0" by the RESET pulse from the Control Logic.

4.2.10 Memory Displays

There is a Memory display associated with each of the six to nine DCU's in the counter. Each display includes a four-bit buffer register, a BCD-decimal converter, and a "Nixie" type neon display tube. Each Memory display has a "read" input and four pairs of data inputs. Normally the data inputs are connected to the parallel outputs of a DCU. When the read input is enabled, information from the DCU is stored in the buffer register,



25 MHz DCU



250 KHz OR 2.5 MHz DCU

TRUTH TABLE

COUNT	1	2	4	8
→ 0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	0	1	0
= 5	1	0	1	0
6	0	1	1	0
7	1	1	1	0
8	0	0	0	1
9	1	0	0	1
→ 10	0	0	0	0

DCU BLOCK DIAGRAM & TRUTH TABLE

FIG 4.2.4

decoded, and displayed as a digit on the display tube. The display is retained after the read input is disabled and stays until new data is read into the buffer register.

When the DISPLAY MODE switch is in the DIRECT position, the memory displays are always enabled. In the STORED mode, they are enabled only at the end of each measurement cycle. In the DIRECT mode the display will start at zero, blur as a measurement is made, indicate the measurement, flash to zero when the instrument is reset, and await the next measurement. In the STORED mode the display will retain each measurement until the succeeding one is complete.

4.2.11 Control Logic

The Control Logic readies the unit for each succeeding measurement and performs a handful of miscellaneous logic functions. It includes a display timer, reset logic, an overflow detector and memory, circuitry to control an external printer or other device, provision for external disabling of the counter, and a 9 volt "reference" source to tell external equipment that the counter is indeed turned on.

a. The Display Timer is a unijunction relaxation oscillator with a period adjustable from about 0.1 s to 5 s or longer by the Display Time potentiometer on the front panel. When the Display Timer pot is rotated full CW, to the EXT RESET position, the oscillator is disabled. The Display Timer generates a 40 μs RESET pulse to the control and counter flip-flops throughout the unit.

b. The Control Logic generates a RESET pulse in any of the following sets of circumstances:

1. Anytime the RESET button on the front panel is pressed.
2. In the DISPLAY mode, when the Display Timer finishes a cycle.
3. In the EXT RESET mode, when the unit receives a RESET command at the RESET connector on the rear panel.

When a RESET pulse is generated for any reason, all action stops. All control flip-flops and counters are cleared to "0". The unit is ready to make a measurement immediately after the RESET pulse.

c. The overflow circuit includes an OVERFLOW flip-flop, an OVERFLOW MEM flip-flop, and a display lamp. The OVERFLOW flip-flop is normally in the "0" state. It is set to the "1" state by the output of the last DCU if the counter overflows, that is

if the most significant DCU attempts a carry to a nonexistent decade. The OVERFLOW MEM flip-flop is loaded from OVERFLOW in the same manner as the Memory Display Buffers are loaded from their DCU's. The overflow signal is a lamp located just to the left of the most significant neon display tube.

d. The Control Logic provides a PRINT COMMAND level at the rear panel data jack. This level is used to control external recording devices. It is true when FINAL STOP is in the "1" state.

e. The Control Logic includes a START ENABLE flip-flop. When the Start Enable switch is in the INT position, START ENABLE is always set ("1" state) except at RESET time, and the unit is always ready to accept a start pulse except at RESET time. In the EXT mode, START ENABLE is cleared and the unit unable to start until a start command is present at the START ENABLE jack at the rear panel. Then START ENABLE is set and the unit ready to run.

START ENABLE is set to "0" during the RESET pulse. This clears the START and STOP flip-flops in the discriminator. When RESET is over, START ENABLE returns to the "1" state.

f. The Control Logic includes a 9 volt source at a source impedance of 300 ohms. This voltage is available at the rear panel data output connector.

4.2.12 Test Pulser

The unit includes a pulser which provides a test pulse 30 μs after the end of the RESET pulse. This pulse is useful in calibrating the unit and is available at a BNC connector on the rear panel.

4.2.13 Power Supplies

All the internal voltages required by the circuitry are provided by an internal power supply. The input voltage is 115 or 230 Vac, selectable by a switch on the rear panel. Line frequencies from 48 to 62 Hz are tolerable.

The unit includes regulated, adjustable power supplies set at ±30V, ±12V, and ±6V. All six voltages are independently adjustable. It also includes a +305V unregulated supply for the neon indicators.

SECTION 3

4.3 DETAILED THEORY OF OPERATION

4.3.1 Introduction

This section describes the circuitry of the Eldorado Electronics Model 796 Time Interval counter in considerable detail. All signal paths and all possible control settings are discussed, each signal is associated with its particular set of components, and all unusual circuits are discussed in detail.

This section is complete unto itself, but a knowledge of section 4.1.2 would make it more easily understandable. Paragraph notations are consistent between this section and section 4.2, so any circuit mentioned there can be easily found here, discussed in greater detail.

The Eldorado Electronics Model 796 Time Interval Counter measures time intervals between electrical events with a resolution of one nanosecond. Its unique circuitry performs this measurement without remarkably fast counters and oscillators and without the one-count uncertainty usually associated with digital counters.

The events timed by the Model 796 can be two independent signals on two independent lines (the TIM mode), the two opposite slopes of a pulse (WIDTH), or two sequential similar slopes of a wave (PERIOD). The unit is capable of measuring 10 ns or so of "negative" time in the TIM mode. The input circuitry is effective over a very wide range of voltages and is insensitive to risetime.

The input circuitry (the attenuators and the Input Discriminators) derive START and STOP signals which are precisely timed by the input pulses.

The START signal turns on the Start Oscillator, a precision VCO controlled by a precision frequency standard. The Start Oscillator is tuned to 10 MHz. The output of this oscillator, controlled by the Add One logic, is counted by the Main DCU's (Decade Counting Units) - - those representing units of 100 ns and more.

The main counter counts until STOP arrives. Then its count is inhibited. The main counters now contain the most significant figures of the time measurement, in nanoseconds. Its count may now be low by one count (100 ns).

STOP also turns on the Stop Oscillator, a VCO similar to the Start Oscillator, but unstabilized and set to a period of 99 ns (about 10.1 MHz). Its output is counted by the interpolator counter, a two-decade counter representing units and tens of nanoseconds.

Both oscillators were designed to start at exactly 0° phase relative to their starting signals. Thus the Stop Oscillator starts out of phase with the Start Oscillator by a time difference equal to the least significant part (less than 100 ns) of the time interval being measured. Each cycle of the Stop Oscillator "catches up" with the Start Oscillator by 1 ns. Somewhere between 0 and 99 cycles, they will be exactly in phase.

The phase crossing of the two oscillators is detected by the Coincidence Gate. This circuit compares the two oscillator outputs and produces a true output when the input square waves have positive transitions which are simultaneous to within 500 ps. The Coincidence Gate output stops the count to the interpolation counter.

At this time the Add One logic is interrogated to find out whether the main counter has missed a count. If so, a count is added.

The two counters now contain a representation of the measured time accurate to within one nanosecond.

The information in the counters is automatically loaded into Memory Displays and displayed prominently on a row of gas display tubes on the front panel. This information can be retained after reset.

At some later time, the instrument is reset, either by its internal Display Timer, by a RESET command from a piece of external equipment, or by manual actuation of the Reset button on the front panel. Both oscillators are stopped, the counters are reset to zero, and the control logic is readied to start another measurement.

4.3.2 Input Attenuators

The Input Attenuators are straightforward sets of 50 ohm pi-networks. Refer to the Multiplier schematic.

4.3.3 Input Discriminator

The Input Discriminator derives START and STOP signals to the counter's control circuitry from the attenuated input signals. The inputs to the Discriminator are the

attenuated input signals, the A and B Trigger Level and Polarity controls, the Start Slope and Stop Slope switches, the Mode switch, the Null potentiometer, an ENABLE level from the Control Logic, and a Test switch inside the chassis. The discriminator outputs are several START and STOP levels to the counter circuitry. All the START and all the STOP signals are coincident, but each is available at several different polarities, levels, and impedances. The Discriminator circuitry includes two versatile, adjustable triggers to derive timing pulses from the input signals, gates to steer the timing pulses as directed by the Mode and Slope switches, two flip-flops (START and STOP) to store the pulses, logic to control and interlock the flip-flops, and a set of output amplifiers.

It will be helpful to refer to the discriminator schematic and illustration 4.2.1 (Discriminator Block Diagram).

a. The two triggers (A and B) are similar except for their output circuits, and will be discussed as one. The description will mention the component numbers in the A trigger, with the parallel component in the B trigger indicated in parentheses ( ).

The output of the A (B) input attenuator is cabled to J2 (J1) on the Discriminator card. There it is terminated to 50Ω by a pair of 100Ω resistors in parallel to ground. Then it is fed to the base of Q3 (Q10), the trigger input. It is also connected across the diode network CR5-CR8 (CR15-CR18). This network limits the voltage at the base of the input transistor to ground ±1.5V. This protects the transistor from excessive voltage from an oversized pulse or an incorrect attenuator setting.

Transistors Q3 and Q4 (Q10, Q11) are connected as a differential switch. Their sum collector current is set at about 10 mA by R14 (R43). Whichever transistor has the more positive base of the pair will conduct nearly the whole 10 mA. Q4's (Q11's) base is set to a DC level somewhere between 1V and -1V by the Start Polarity and A Trigger Level (Stop Pol., B Trig. Level) controls. Each transistor base is decoupled by a pair of R-C networks to assure pure DC voltages and to avoid interaction with the input transistors.

Tunnel Diodes CR2 and CR3 (CR13, 14) have a forward voltage drop of 0.1V when their forward current is more than zero but less than 5 mA. When 5 mA or more is put through either diode, its voltage drop increases to about 0.5V. Its drop stays at 0.5V until its current is decreased to 2 mA or so. Tunnel diodes change state very quickly - - in a matter of picoseconds.

In this circuit, one diode is usually "on" (in its high-voltage state) and the other off. There is a region about 0.1V wide (± 50 mV) selectable by the Trigger level control where both diodes may be on at once. Thus the instrument is limited to signals of 100 mV magnitude or more.

Assume now that the base of Q4 (Q11) is more positive than that of Q3 (Q10). CR3 (CR14) is on, CR2 (CR13) is off. Now assume that the input voltage is gradually increased. Eventually the input voltage at Q3 (Q10) will exceed the trigger level and Q3 (Q11) will start to conduct. Soon tunnel diode CR2 (CR13) will draw 5 mA and turn on. This will turn Q1 (Q7) on until C2 (C11) charges to its new voltage. This takes about 10 ns. A 10 ns positive pulse therefore appears at the base of Q6 (Q9). This pulse is called A+ (B).

Meanwhile, the other tunnel diode has turned off. As the input signal decreases, it again crosses the trigger level, and CR3, Q2, and C3 (CR14, Q8, C12) produce an A- (B) pulse at the base of Q5 (Q9).

Note that the polarity indications of the A+ and A- pulses indicate the trigger slope and not the input voltage polarity. A+ can occur on a negative voltage, or vice versa. Note also that two B pulses seem to be produced, one on each slope of the input. In fact, one or the other of the B pulses is inhibited by the Stop Slope switch through gate diodes CR9 and CR10. Only one B pulse appears per stop input cycle.

Emitter followers Q5, Q6, and Q9 lower the impedance of the A-, A+, and B pulses respectively.

b. Q17 is the input transistor to the START flip-flop, and Q26 the input to the STOP flip-flop. The three trigger pulses are steered to these transistors by the Mode and Start Slope switches through diodes CR19-CR42.

The gating is probably clearer on the block diagram than on the schematic - - the system is simple, but difficult to draw. Simply, one of two pulses, A+ and A-, is allowed to arrive at the base of Q17. The other pulse is inhibited by the gates as shown in the following table. Similarly, only one of the three pulses is ever allowed to arrive at Q26. The others are inhibited as shown below.

Mode	Start Slope	Start Pulse	Stop Pulse	Pulses Inhibited
TIM	+	A+	B	A-
TIM	-	A-	B	A+
PERIOD	+	A+	A+	A-, B
PERIOD	-	A-	A-	A+, B
WIDTH	+	A+	A-	B
WIDTH	-	A-	A+	B

Table 4.2.1 Mode Functions

c. Tunnel diodes CR44 and CR50 are the START and STOP flip-flops respectively. Each requires 10 mA to turn on. Each can be set only when its input is pulsed and when it is enabled by its external circuitry.

The START flip-flop is set by the differential pairs Q18/Q19 and Q12/Q13. The diode can not be set unless both Q12 and Q18 are conducting. Q12 is on unless the instrument is in the EXT ENABLE mode and not enabled or being reset. Any pulse at Q17, then, turns on Q18 and sets CR44. The quiescent current through Q12 is enough to keep CR44 on after the trigger pulse is over and Q18 turns off again. The small level shift at the cathode of CR44 is amplified by the differential pair Q15/Q16 to increase it to a usable level.

Tunnel diode CR50, the STOP flip-flop, will not fire unless both Q31 and Q27 are on. Q27 is held off by Q16 until the START flip-flop is set, thus interlocking the logic. RC network R93/C27 acts as a 50 ns delay to Q31 when its switch, Q28, is turned on, and a closed circuit otherwise. Q28 is turned on only in the period mode.

In the TIM and WIDTH modes, STOP is enabled as soon as START is set. Since the output of Q26, the STOP driver transistor, is delayed about 38 ns by a passive cable delay, the STOP flip-flop can actually be set by a signal that arrives a few nanoseconds before the START signal. This allows measurement of "negative time" down to about -10 ns. The instrument can be used as a chronological null meter to detect simultaneity between pulses.

In the PERIOD mode, the STOP flip-flop is inhibited by the 50 ns delay (R93/C27) until well after START has been set. This keeps the simultaneous start and stop pulses in this mode from tangling up in the logic and, unfortunately, keeps the unit from measuring signals of less than 50 ns. The output of the STOP tunnel diode is amplified by the differential pair Q33/Q34. The DC level at the STOP output is adjustable by the NULL potentiometer on the front panel. Since the STOP signal has a risetime of about 10 ns, the potentiometer adjusts the timing of its zero crossing a few nanoseconds each way. Since the Start Up Oscillators turn on at zero volts input, this adjustment allows the fine timing of the entire unit to be adjusted to compensate for component aging or external cable delays.

Q14, CR43, and the differential pair Q12/Q13 comprise the ENABLE and reset circuit. Normally, Q14 is turned on, effectively grounding the node of R64 and R72 and turning tunnel diode CR43 on through R71 and R72. This turns Q13 off and thus Q12 on, drawing enough current through CR44 to enable it to be set when the next start pulse comes along. At the end of each cycle, the instrument is reset, and the ENABLE line turns Q14 off for about 50 μs. This back biases and thus extinguishes the tunnel diode, reverses the differential pair, and turns off CR44. This in turn turns off the STOP flip-flop CR50, as its enable level from Q27 is removed. When the reset signal goes away and Q14 turns on again, the instrument is ready to accept another set of inputs.

In the EXT START ENABLE mode, Q14 is off and the START flip-flop disabled until an external start signal is received from a piece of external equipment. This is discussed more fully under the heading Control Logic, sec. 4.3.11.

d. Q20, Q21, and Q23 are output buffers for the START signal. Q29 and Q32 are output buffers for the STOP signal.

4.3.4 Start Up Oscillators

The Start Oscillator and the Stop Oscillator are similar. They are discussed here as one. Refer to the Start Up Oscillator Schematic.

Q1 and Q2 comprise a fast, high-gain switch. When the input voltage to the GATE input passes ground, both Q1 and Q2 turn on, and the output of Q2 goes from -6V to +6V. The trigger level is set at ground by the forward drop of CR1 and the base-to-emitter drop of Q1. The output risetime of Q2's collector is deliberately slowed by the network R6/C1 to optimize the turn-on characteristic of the oscillator.

When the gate is opened, CR2, which until now has been conducting through L1 and holding the base of Q3 negative, goes out of conduction and allows the oscillator to start. Components L1, C2-C8, and varicap diode CR3 comprise the oscillator tank circuit. The output frequency of the oscillator is trimmable by C2 and variable by CR3. A positive DC voltage applied to the VCO input will change the capacitance of the diode and thus vary the resonant frequency of the tank. Q3 and Q4 are a Darlington pair which, with the tank circuit and feedback loop R13/R7, form a Colpitts-type oscillator. Zener diodes CR4 and CR7 add the proper DC level to the output signal and stabilize the oscillator gain at unity. Diodes CR5/CR6 limit the amplitude of the feedback signal. Ferrite beads FB1 and FB2 stifle any possible VHF parasitic oscillations.

Transistors Q5-Q8 and their associated components amplify and square the output of Q4, producing complementary square-wave outputs at the + and - output terminals. Inductors FB3 and FB4 improve the output risetime.

In the Model 796, the Start Oscillator is gated on by a START output of the discriminator. This output is delayed about 41 ns (the exact delay is selected at test) by a length of cable and fed to the start oscillator. The trimmer capacitor and DC VCO input are adjusted to bring the oscillator as closely as possible to 10 MHz. In actual operation, the Start Oscillator is stabilized at 10 MHz by the stabilizer through its VCO input.

The Stop Oscillator is enabled immediately by the STOP output of the discriminator. Its output frequency is set by a chassis-mounted pot to about 10.1 MHz (period 99 ns). The Stop Oscillator is not stabilized.

The portion of each oscillator shown inside the dotted line on the schematic is enclosed in a thermostatically-controlled oven. The ovens operate from 117 Vac and are operative whenever the instrument is plugged in, regardless of the position of the power switch.

4.3.5 Stabilizer Circuits

The stabilizer circuits include a 1 MHz precision oscillator, a VHF multiplier-divider circuit, and a phase lock comparator.

a. The standard reference oscillator is shown in the Reference Oscillator schematic. It is a conventional crystal oscillator, trimmable by C1 and C2. It is temperature compensated but is not mounted in a temperature controlled oven.

Oscillator options C, D, and E are not manufactured by Eldorado and no schematics are usually available for them. Option C has a thermostatically controlled 115 Vac oven. Options D and E have proportionally controlled 24 Vdc ovens. Units with option D or E installed are fitted with an oven power supply as shown in the Oven Power Regulator schematic, A-11-04949.

In any case where the oscillator is enclosed in an oven, the oven is enabled whenever, the unit is connected to an AC source, whether or not the power supply is turned on.

b. The multiplier-divider circuit accepts 1 MHz at 1V rms from the internal standard (Reference) oscillator or from an external frequency standard. It amplifies the signal, multiplies it to 80 MHz, gates it with a START signal, and divides it back down to 10 MHz. The high-frequency gating lets the original phase difference between the 10 MHz Start Oscillator and the now 10 MHz standard be known within a few degrees and permits higher system gain later on.

The 80 MHz multiplier includes transistors Q1-Q7 and the associated tuned circuits and other components. Q1, Q2, and Q3 form a high-input-impedance Schmitt trigger that amplifies and squares the input signal. The square-wave output is deliberately clipped and distorted by R13, L1, CR1, and C10 to enrich its harmonic content before feeding it to the first multiplier, Q4. Q4, Q5, and Q6 are class C RF multipliers. Q4's tank is tuned to 5 MHz, Q5's to 20 MHz, and Q6's to 80 MHz. Thus the transistors multiply by 5, 4, and 4 respectively and produce an 80 MHz output. That output is amplified and smoothed by RF amplifier Q7.

The divider consists of integrated circuits MC1-4, transistors Q8-Q11, and the associated resistors and capacitors. All the integrated circuits are Motorola high-speed ECL (Emitter-Coupled-Logic). MC1 is a dual NAND gate. MC2 is a 100 MHz J-K (complementing) flip-flop. MC3 and MC4 are 70 MHz J-K flip-flops.

C32 couples the output of Q7 to the input of MC1A and voltage divider R32/R33. The voltage divider sets the proper DC level, in this case about -1.6V, to trigger the logic. MC1A squares the 80 MHz signal and feeds it to MC1B.

A START output of the discriminator is delayed by about 18 ns by a passive delay cable and fed to J1, the gate input of the divider. This signal is inverted by Q8 and gated with the output of MC1A at MC1B. After the arrival of the delayed START signal, MC1B is enabled, and it starts to drive the divide-by-eight string MC2-MC4.

Q9 through Q11 amplify the output of MC4 and feed it to the stabilizer board through J4.

Since the gating occurred at 80 MHz, and the count string started at zero, the output signal is in phase with the START signal within one-eighth cycle. Since the divider was started about 24 ns before the Start Oscillator, we know that the Start Oscillator and the divider are originally about one-quarter cycle out of phase.

This knowledge allows higher gain and greater accuracy in the comparator circuit.

The RESET pulse from the Control Logic clears the divide-by-eight counter to zero at the end of every measurement cycle.

c. The phase comparator circuit (the stabilizer PC board) includes a phase detector, a versatile differential amplifier that can be used as an integrator or a comparator, a capacitor voltage memory, an analog switch to allow the Start Oscillator to be controlled by either a potentiometer or the output of the differential amplifier, and the logic and timing circuitry to control all these. Refer to figure 4.2.2 Stabilizer Block Diagram and the stabilizer schematic.

The outputs of the Start Oscillator and the Divider are cabled to J1 and J2 on the stabilizer board, loaded to 50Ω to match the cable, and compared by NOR gate Q1/Q2. The output of this gate is a string of pulses at a repetition rate of 10 MHz. The width of the pulses is proportional to the phase difference between the two signals. The pulses are integrated by L1 and C1 and fed to the base of Q4 as a DC level.

Q4 and Q5 are connected as a differential amplifier. Q6 is their current source - - the sum current of the amplifier and thus its gain can be adjusted by the Start Oscillator adjust pot on the inside of the chassis. The output of Q4 is again amplified by the Darlington pair Q9/Q10 and fed through the now open diode string CR5/CR22/CR6/CR23 to C8, the memory capacitor. This voltage is buffered by the source follower FET Q8 and fed to the opposite input of the differential amplifier, the base of Q5. Assuming that the Start Oscillator is reasonably close to 10 MHz, the amplifier soon reaches a steady state, with the base voltages of Q4 and Q5 equal. Four microseconds after

START time, the MEMORY GATE flip-flop sets, backbiasing the diode string and locking the voltage across C8, thus holding the base of Q5 at a constant voltage. The output of the differential amplifier will now change proportionally to any change in the phase difference between the two oscillators. This error signal is amplified by Q7.

Eight microseconds after START, (assuming that the signal to be measured is longer than eight microseconds), the 8 μS GATE Flip-flop is set, switching analog gate CR16-CR21. Originally, the output voltage at J3 (the cable to the Start Oscillator VCO input) was determined by the setting of R68. Now, it is determined by the output voltage of Q7. Any phase change is quickly tuned out by the comparator, and the Start Oscillator is locked in a loop with the frequency standard.

The four-microsecond timing of the MEMORY GATE flip-flop is derived by the MEMORY DELAY one-shot, Q13/Q14. An undelayed START signal is fed to C17, where it triggers the one-shot. The principal timing components are C15 and R43. The resetting of the one-shot triggers the MEMORY GATE flip-flop, Q11/Q12. Note that this is a complementary symmetry flip-flop - - both its transistors are either on or off simultaneously. Originally, both transistors are cut off. The diode string CR5/CR22/CR6/CR23 is conducting, and the output of the Darlington Q9-Q10 is free to charge the memory capacitor C8. The output of the MEMORY DELAY one-shot now turns on both flip-flop transistors. The top of the diode string is brought to -6V through CR8, and the bottom to +6V through CR7. The diode string is back biased. C8 can now only be discharged by the leakage current of the diode string, the input current of the FET, and its own leakage current. All of these discharge the capacitor negligibly over the 1 s or less it must retain its charge.

The 8 μS GATE is another control flip-flop. Its output drives the analog gate CR16-CR21 that selects the drive to the Start Oscillator VCO input. The 8 μS GATE flip-flop is set through C21 by the DCU flip-flop that indicates 8000 ns. Of course, if the signal measured is less than 8000 ns long, the flip-flop will never fire. The Start Oscillator is sufficiently stable that it is accurate for short-term measurements. When the flip-flop does set, however, it switches the comparator output to the VCO input of the Start Oscillator.

Both the MEMORY GATE flip-flop and the 8 μS GATE flip-flop are set back to their "0" states by the RESET pulse from the control logic.

4.3.6 Coincidence Gate

The coincidence circuit is probably the most unusual circuit in the Counter. It produces an output pulse when and only when the outputs of the Start and Stop Oscillators are simultaneous to within 500 ps.

The outputs of the VCO's are cabled to J1 and J2, where they cycle tunnel diodes CR1 and CR3 repeatedly. The two tubular-looking illustrations on the schematic B-11-04803 indicate delay lines - - lengths of RG-188/U coaxial cable, open at the bottom end. The cable lengths are critical and the cables are carefully pruned to length during the instrument's testing.

Each time a tunnel diode (CR1 or CR3) fires, the output (inner conductor) of its delay line shows an approximately square pulse of magnitude 0.4V and duration 500 ps.

Tunnel diode CR3 is so biased by potentiometer R6 and the associated components that it will be set when and only when it is pulsed by both delays simultaneously. Its output is coupled to Q1 through R8 and C3 and amplified by Q1 and Q2. The coincidence output at J3 is a single positive pulse.

The 500 ps time mentioned above, as well as the word "simultaneously", are used fairly loosely here. Measurements within the coincidence circuits are well-nigh impossible to make without altering their performance drastically. It would be wise to touch this circuit as little as possible.

4.3.7 Stop Logic

The Stop Logic controls the interpolation counter - - the two least significant DCU's. It includes a stop gate, a FINAL STOP flip-flop, and an OVER 8 flip-flop. See the Stop Circuit Schematic C-11-04943.

The stop gate consists of Q4 and CR5. Until coincidence time, the output of the Stop Oscillator is inverted by Q4, inverted again by Q5, and cabled to the input of the interpolation counter. When the coincidence pulse arrives and the FINAL STOP flip-flop is set, CR5 is grounded, disabling the output of Q4 and stopping the count.

The FINAL STOP flip-flop consists of Q6 and Q7. The positive output pulse of the coincidence circuit is coupled to Q6 through CR4. It sets FINAL STOP, providing that the OVER 8 flip-flop is set.

It would be undesirable to trigger a coincidence pulse from the first cycle of the Stop Oscillator. Therefore, the stop circuit is disabled for the first count. In fact, since it does no harm, the circuit is disabled for the first eight counts. The OVER flip-flop, Q1/Q2 is set by the output of the 4 ns DCU flip-flop. When it is set, R9 is effectively grounded, enabling FINAL STOP to be set through C4. If the first coincidence pulse appears at the Nth cycle of the Stop Oscillator, where N is less than 8, the counter waits for the second coincidence pulse, which should appear at 100 + N counts, to arrive. The extra counts simply overflow the interpolation counter and are lost.

The output of the FINAL STOP flip-flop is buffered by Q3.

Both FINAL STOP and OVER 8 are cleared to "0" by the RESET pulse from the control logic, through CR6 and CR3 respectively.

4.3.8 Add One Logic

The Add One Logic controls the count to the main DCU's from the Start Oscillator and disallows the quantizing error of the counter. It also includes the logic that indicates the measurement of "negative time". The logic includes two flip-flops, READOUT and -COUNT, and the logic to operate them.

The READOUT flip-flop includes transistors Q16 and Q17. Transistors Q4, Q15 and Q18 are direct set and clear inputs to READOUT. The output of the Start Oscillator is cabled to J2. J1 is simply a cable connection to bus the Start Oscillator output to the Stabilizer as well. The 10 MHz signal is inverted by Q4. The READOUT flip-flop is set by Q4's collector and cleared by its emitter. Thus each cycle of the Start Oscillator drives READOUT through one complete cycle as well. The READOUT flip-flop follows the oscillator and does not perform a divide-by-two function. Q4 is unable to set or clear READOUT unless either Q5 or Q6 are turned on.

READOUT is enabled through Q5 until 110 ns or so after START appears. START is delayed 110 ns by the network R1/C1, inverted by Q1, and fed to Q5. This means that under any conditions, READOUT is allowed to set at least once. This is essential for the accurate measurement of times from 100 to 199 ns. After Q5 turns off, the flip-flop is enabled by Q6 until 20 ns after the STOP signal arrives. STOP is delayed 20 ns by a three-stage lumped-constant L-C delay and fed to the base of Q6. 20 ns after STOP, Q6 is off and the READOUT flip-flop is disabled.

The output of the READOUT flip-flop is inverted by Q3 and fed to the main DCU's. For the first 110 ns after START (the first half cycle of the Start Oscillator, taking all the delays into account), the output of Q3 is inhibited by Q2 through Q1 and its delays.

When the FINAL STOP flip-flop in the Stop Logic is set, the READOUT flip-flop is interrogated through the gate CR9/CR10 and the trigger transistor Q18. If the count in the interpolator counter is greater than 80, the interrogation is inhibited through CR9. If the interrogation pulse gets through, and the READOUT flip-flop is in the "0" state, the interrogation pulse sets it and adds one count to the main DCU. If the READOUT flip-flop is already in the "1" state, nothing happens.

The -COUNT flip-flop, Q10/Q11, is set if the STOP level arrives less than 75 ns or so after the START signal. START is delayed 75 ns by the network R21/C8 and ANDed with the undelayed STOP signal by Q7 and Q8. If the output of this gate is ever true, Q10 will be set through C12 and Q9. The -COUNT flip-flop is thus set for counts between about -15 ns and +15 ns. "Negative time" is displayed by the 796 as the 100 ns complement of the time measured. That is to say, -6 ns is indicated as 94 ns with a negative indication on the front panel. To eliminate the erroneous negative indication for times from 0 to 15 ns, the -COUNT flip-flop is reset by FINAL STOP if the interpolator counter stands at less than 80 ns. The components involved are Q13, Q14, and CR4. Q12 samples the output of the -COUNT flip-flop and lights an indicator on the front panel when -COUNT is true.

Both flip-flops are reset by the RESET pulse from the Control Logic, READOUT through CR7 and -COUNT through CR3.

4.3.9 Decade Counters

The Model 796 includes three types of decade counters. All are externally similar except for their frequency response. Refer to Figure 4.2.4 DCU Block Diagram and Truth Table and the schematics, dwg. D-11-03968, 03967 and 03966.

Each counter is a standard 1-2-4-8 decade divider including four J-K flip-flops and the necessary gating. The 25 MHz counters have an emitter follower output to the first stage, and a three-input gate to speed the carry to the "8" flip-flop. The slower decade counters are utterly conventional.

The components associated with each flip-flop and gate are indicated on the block diagram.

All the DCU's are reset to zero by the RESET pulse from the control logic.

Each DCU has a reset-to-nine input and a nine-true output. Neither of these are used in the Model 796.

4.3.10 Memory Displays

There is a Memory Display module associated with each of the six to nine DCU modules in the Model 796. All the Memory Displays are identical. Each contains a four-bit buffer register with read logic, a binary-to-decimal converter and a gas display tube. The tube is mounted on the printed-circuit card in such a manner that it is visible from the front panel.

Transistors Q1 through Q8 are paired into four flip-flops. Each has two DC set inputs, connections to the read line, and outputs to the display decoders.

When the Model 796 is in the stored display mode, as it is usually, Q19 is cut off until it receives a READ pulse through R1. While it is cut off, the read line (the bus extending from the node of R3, R4, and R6) is held positive. The input levels to the flip-flops (for example, R7 and R12) have no effect on the flip-flops. When the READ pulse arrives, all the inputs are enabled and each memory flip-flop assumes the state asked by its inputs. In the Model 796, each memory module is connected to a DCU. FF1 of the DCU is connected to Q1/Q2, and so on. Thus, when a READ pulse arrives, the contents of each DCU are loaded into its associated memory module.

Transistors Q9-Q18 are the high-voltage switching transistors that drive the readout tubes. When any transistor is turned on, its associated tube cathode lights up. Components CR1-3 and R38-R46 decode the BCD output of the memory flip-flops and light the proper cathode.

Q20 and R51-4 provide data to the printer output connector on the rear panel.

4.3.11 Control Logic

The Control Logic performs several miscellaneous functions around the unit. Most importantly, it includes the rest and display timer circuitry, which sets the initial state of the instrument and resets it to that state after it has completed its measurement, all the while storing data in the memory displays. It includes the START ENABLE flip-flop, which resets the discriminator and allows the unit's starting to be externally

inhibited. It also includes overflow detection and memory and a nine-volt source to tell external equipment that the Model 796 is indeed turned on.

Transistors Q6 through Q13 are involved with the RESET pulse. First, the base of Q6 receives a reset command from the display timer or some external source. This triggers the Schmitt Trigger Q6/Q7 and starts the 50 μs one-shot Q8/Q9 through CR5. Alternately, someone presses the Reset button on the front panel. C9, which has previously charged slowly to 6V through resistor R29, is discharged quickly through R28. This pulse is coupled to Q8 through C12 and CR4, and thus starts the one-shot. The R-C constants associated with the pushbutton keep any contact bounce from producing spurious reset pulses. After C13 and R36 time out 50 μs, the one-shot returns to its original state.

All this produces a 50 μs negative pulse at the base of Q11. Q11 inverts the pulse, amplifies it, and feeds it to the bases of the parallel emitter followers Q12 and Q13. These produce the positive reset pulse (-6V to +6V) that clears the control circuitry throughout the unit. Q10 inverts the pulse yet again and provides a RESET signal to the DCU's.

The display timer is a unijunction relaxation oscillator based around Q20. Its period is adjustable from about 0.1 s to 5 s or more by the Display potentiometer on the front panel.

When FINAL STOP sets, it turns Q18 off, firing the 60 μs READ one-shot Q15/Q16 and turning off Q19. The 60 μs READ pulse is fed to the Display Mode switch. In the STORED mode, the read pulse temporarily enables the read lines of the Memory Displays and loads them with the contents of the DCU's. In the DIRECT mode, the Memory Displays are always enabled, so the READ pulse is ignored. In the POWER OFF mode, of course, none of this ever happens.

Meanwhile, Q19 has turned off. This allows C17 to start charging through R61 and the Display Time pot. Eventually, unijunction transistor Q20 breaks down, producing a pulse that is fed to Q6, where it starts a RESET cycle as described above. In the EXT RESET mode, selected by a switch on the Display pot, the output of the display timer is ignored and the 796 waits for an external reset pulse at the reset connector on the rear panel.

The overflow-detection circuit includes the flip-flops Q22/Q23 (OVERFLOW) and Q24/Q25 (OVERFLOW MEM). OVERFLOW is similar in configuration to a DCU flip-flop. It is set through C20 and CR13 by the negative RESET pulse. OVERFLOW MEM is similar in configuration to a memory flip-flop. It reads the output of OVERFLOW exactly as, and under the same conditions as, a Memory Display reads its DCU. The output of OVERFLOW MEM is monitored by Q27 and displayed on the front panel.

Transistors Q1 through Q5 comprise the Start Enable circuit. When the Start Enable switch, a recessed slide switch on the rear panel, is in the INT position, the START ENABLE flip-flop Q4/Q5 is forcibly set by about 20 volts of back bias on the base-to-emitter junction of Q4. The RESET pulse puts the flip-flop in an invalid state where both transistors are off for 50 μs. The output of Q5 then clears the discriminator flip-flops as described in the discriminator section.

When the Start Enable switch is in the EXT position, the START ENABLE flip-flop is in the "0" state, and the discriminator disabled, until the unit is externally started. The input Start Enable signal flips the Schmitt Trigger Q1/Q2/Q3 and sets START ENABLE through C6 and CR2. START ENABLE will later be cleared by RESET and will stay cleared till another Start Enable pulse arrives or it is switched back to the INT mode.

The PRINT COMMAND is a -12 volt level which is true when FINAL STOP has been set. It is used to inform external equipment that the 796 has completed a measurement and that its registers are loaded with data. It is derived from the output of Q18 by Q14 and is available on the rear panel data connector.

The PRINT INHIBIT input disables the display timer, and thus prevents an internal reset, until a reset is allowed by some external piece of equipment. It allows external equipment to hold information in the 796 till it is ready to receive it.

The -9V "reference" signal is derived from the -12V supply by the voltage divider R46-R47. This signal is available at the rear panel data connector.

4.3.12 Test Pulser

The Test Pulser provides a test pulse about 30 μs after RESET. It includes a 30 μs timer and an avalanche pulse former.

The RESET pulse triggers the one-shot Q1/Q2. Its time constant is set by C4 and R5. Its output is a 30 μs positive pulse at the collector of Q2.

This pulse is differentiated and rectified by C6 and CR2. Its negative slope is inverted and amplified by Q3. Its output is a 20 volt positive pulse. This pulse is coupled to the collector of Q4 by C8.

Q4 is a type 2N3646 transistor especially selected for its breakdown voltage. Its collector is biased by R18 so that its bias voltage plus the 20 volt pulse from Q3 will cause it to avalanche. When Q4 breaks down, it produces an 8 ns pulse of magnitude greater than 15V and a risetime of less than 2 ns at its emitter. This pulse is cabled to the rear panel Test Pulse connector.

4.3.13 Power Supplies

The power supplies derive regulated voltages of ±30V, ±12V, and ±6V from the AC power line. They also produce an unregulated level of +305V or so to illuminate the display tubes and operate the Test Pulser. The supply is operable from 115 or 230 Vac, 48-62 Hz. Refer to the power supply schematic D-11-04917.

All the power supplies except that for the oscillator oven in options D and E are controlled by the Power switch, which is ganged with the Display Mode switch. The power switch controls the power to transformer T1. T1 has two primaries, which are connected in parallel for 115V operation and in series for 230V operation. The connection is switchable by a control on the rear panel. In the 230V mode, T1 acts as an autotransformer to drive the 115V fan motor.

Power is applied to the oscillator ovens whether or not the power switch is turned on.

T1 has three secondaries. One provides 76VCT for the ±30V supplies, one provides 28VCT for the low-voltage supplies, and one provides 215V to the high-voltage rectifier. The center taps of the two low-voltage windings are grounded, and the transformer outputs are bridge rectified, to derive both positive and negative voltages from the same winding. CR5-CR8 provide ±36V for the 30V regulators and CR9-12 ±14V for the ±12V and ±6V supplies.

Zener diode CR4 provides a -6.2V reference voltage which is compared to the -30V output signal by Q9 and the resistor string including the -30V adjust pot, R8. This error

signal is amplified by Q9 and fed to the -30V series regulator transistor, Q1, through emitter follower Q8. The -12V regulated voltage is derived directly from the -30V supply by R6, R7, the pot R39, and the Darlington pair Q7/Q2. The -6V output is compared with the reference diode CR4 by the differential pair Q14/Q15. The error signal is fed to Q3, the -6V series regulator, through emitter follower Q13. Note that the lower voltages are both dependent on the -30V supply for their stability. Any adjustment of the -30V supply will throw both the other supplies off.

The positive regulators work similarly, except obviously are oppositely polarized. CR15 provides a reference of +6.2 volts which is compared to the +30V output by Q11 and the resistor string around R21. Q11 amplifies the error signal, which is fed to series regulator Q4 through emitter follower Q10. The +12V output is derived from +30V by the voltage divider, R24/R25/R28. The voltage is amplified by Q12 and fed to series regulator Q5. The differential pair Q17/Q18 compares the reference voltage to the +6V output. Their output is amplified by Q16 and applied to series regulator Q6. As in the negative regulator, the supplies are interdependent.

All the voltages are filtered by large capacitors. The low-voltage supplies are fused, as is the AC input.

CR1, C12, and bleeder resistor R40 form the +305V supply. This output can safely vary ±20% without causing trouble.

4.4 THEORY OF OPERATION - - OPTION J

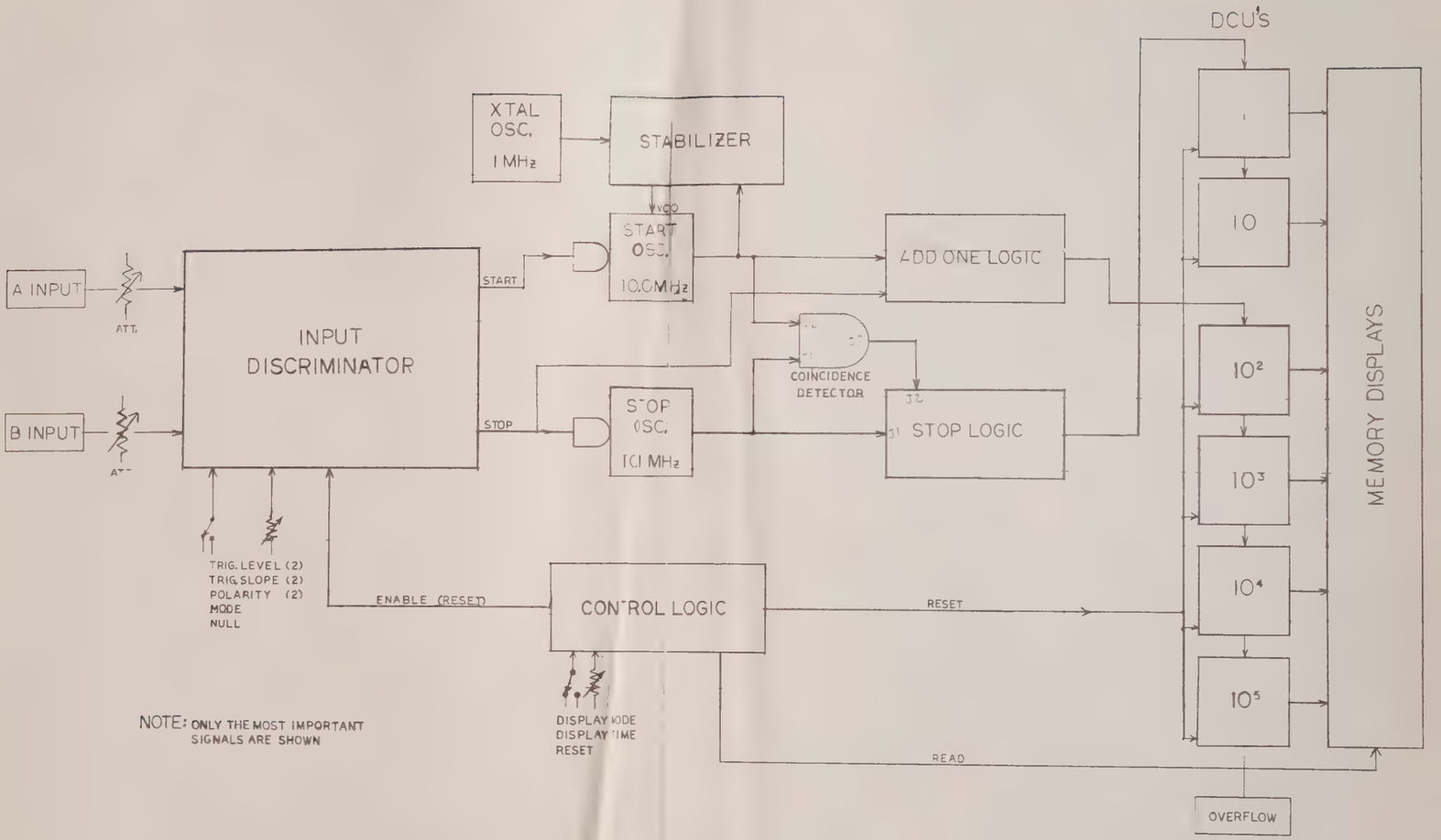
Option J is the only standard 796 option that includes a significant amount of extra circuitry. The option provides for remote programming of the instrument's trigger mode, trigger level, trigger polarity, and trigger slope.

The modifications include an extra position and several extra poles on the Mode switch, a REMOTE CONTROL connector on the rear panel, and a board of inverters in the logic chassis.

In the REMOTE position, the mode switch disables all the front panel trigger controls except the input multipliers. The trigger functions are controllable remotely through the rear panel connector. The connections and drive requirements of the remote connector are listed in table 3.2.4. The remote control switches and cable are supplied

by the user and wired as described in the table. Control can be by means of a manual switchboard, a relay bank, or a network of switching transistors. Trigger voltage adjustment may be made by a potentiometer, as shown, or by the output of an operational amplifier capable of driving a 50 ohm load.

The switch outputs are amplified and inverted if necessary by the remote slope and mode card. The outputs of this card are fed through the mode switch to the discriminator. This keeps the direct discriminator wiring to a reasonable length.



MODEL 796
SIMPLIFIED BLOCK DIAGRAM

CHAPTER 5

MAINTENANCE AND CALIBRATION

CHAPTER 5

MAINTENANCE AND CALIBRATION

5.1 GENERAL

This section includes two parts. The first is a short list of preventive maintenance procedures. These are intended as much to maintain operator confidence in the counter as to keep the counter in good condition. The second part discusses two calibration procedures, one short and one long, and indicates when either should be used. It also mentions the several adjustments within the 796 that will probably never be touched for the life of the instrument.

5.2 MAINTENANCE

5.2.1 Weekly

1. Check the instrument against a Model 420 or 421 calibrator as described in the calibrator manual or as described in section 2.3.1. If no such calibrator is available, use a 1 MHz standard as described in the same section. Adjust the Null potentiometer if necessary.
2. While making the above checks, see that the controls rotate freely, that all cables are properly connected, that the indicator tubes light clearly, and that the fan is blowing smoothly.
3. Check the internal 1 MHz oscillator against a frequency standard. If it seems to be out of adjustment, see the calibrator section of this chapter. Do not adjust the oscillator until you have read the pertinent parts of the calibration section.

5.2.2 Bimonthly

The following procedure should be carried out every 60 days. The fan filter, especially, MUST be cleaned every two months, and more often in dusty environments.

A. Cleaning and Inspecting

1. Turn the instrument power off, disconnect all cables except the line cord, and remove the unit from its rack, if any. Keep AC power applied

to the unit as much as possible. If you must unplug it, plug it in again as soon as you can.

2. Clean the outside of the unit if it seems necessary. Dust it gently with clean, dry compressed air. Remove any accumulated grease from the controls and panels with a mild detergent solution or 50/50 ethanol and water. Other solvents may damage the paint and the display filter.
3. Remove the mesh filter from the cooling fan. Clean it with detergent or solvent, spray it with a sticky commercial filter-cost solution, and replace it.
4. Remove the top and bottom covers. Dust the interior carefully with clean, dry compressed air. Pay special attention to the display tubes and the area near the hot oscillator ovens.
5. Give the unit a careful mechanical inspection. See that all the controll operate smoothly and that all knobs are tight. Test-fit all connectors with the correct mating fittings. Check the internal cables for tight connections. Check the capacitor clamps and screw connections. Inspect the fan and see that it is clean, and not bent or jammed. Turn the power on for a moment and see that the fan spins quietly and in balance.
6. It is neither worthwhile nor advisable to remove the circuit boards to inspect or burnish their contacts. All the contacts are gold-plated and non-corrosive. The dangers of misplaced cables and boards knocked out of alignment are more significant than the possibility that a defective contact might be found.
7. Check for scratched and chipped paint. If the proper paint is available, touch up any spots that need it.
8. Replace the covers.

B. Testing

1. Check the instrument with an Eldorado Model 420/421 calibrator or an external frequency standard as described in section 2.3.1. Adjust the Null potentiometer if necessary.
2. Check the instrument in the WIDTH and PERIOD modes. Use a variety of input signal times, levels, and polarities. Try to use each control (except the multiplier) in all of its positions. Bear in mind that this is a function test of the unit and not a calibration test - - the 796 is probably more accurate than whatever you use to test it.

3. Inspect the display tubes carefully. As they age, their illumination changes from a clearly defined number to a vague blue-purple glow. Replace any tubes that seem to be failing.
4. Put the unit in the EXT RESET mode. Verify that it can be reset by a negative pulse at the Reset jack.
5. Put the unit in the EXT START ENABLE mode. Verify that it will not start until it has received a negative pulse at the proper jack on the rear panel.
6. Compare the 1 MHz oscillator output with a frequency standard. Display the two oscillators as a Lissajous pattern, and see that they are synchronous within the specifications given in the data sheet. Do not adjust the internal oscillator unless 1. the external standard is known to be good AND 2. the oscillator has had adequate warmup time.
7. If the instrument seems out of calibration or fails to function in any mode, see the calibration section of this manual. Do not attempt any internal adjustments without further information.

5.3 CALIBRATION

The Model 796 includes only solid state circuitry. Since most of its circuit constants are fixed, it should require little or no periodic calibration. Usually the instrument will be accurately settable by means of the null control. Occasionally, the Stop Oscillator will have to be adjusted and the 1 MHz standard trimmed. Less often, the stabilizer and Start Oscillator will have to be adjusted. As on any electronic instrument, random twisting of internal adjustments is to be avoided. A few careless misadjustments may require hours of time and much expensive equipment to correct. Adjust trimmers only as absolutely necessary, and then only a fraction of a turn at a time. Record each adjustment as it is made, so that you can return to the starting point if necessary.

5.3.1 Internal Adjustments

The following is a list of the trimmer resistors and capacitors in the Model 796 which may have to be adjusted from time to time.

1. STOP OSCILLATOR. This is a potentiometer mounted on the center main chassis near the oscillators. It controls the frequency of the Stop Oscillator.

2. START OSCILLATOR is another potentiometer on the center chassis. It controls the gain of the stabilizer board.
3. START OSCILLATOR ADJUST is a trimmer capacitor inside the Start Oscillator can. It is best reached with a long, thin, fiber screwdriver. Adjust the capacitor only with great care to avoid physical damage to the oscillator components. Do not use a metal screwdriver.
4. STABILIZER is a 100Ω potentiometer on the stabilizer card. This adjusts the static output of the stabilizer, and thus the center frequency of the Start Oscillator.
5. 1 MHz OSCILLATOR ADJUST. This trimmer capacitor compensates for the aging of the 1 MHz oscillator crystal. It is located on the 1 MHz oscillator can. Oscillator options D and E have both coarse and fine adjustments.

5.3.2 Fixed Internal Adjustments

The following internal controls will probably need never be touched. They are listed for reference only.

1. POWER SUPPLY ADJUSTMENTS. These six potentiometers (identified on the chassis layout) on the power supply cards adjust the ±30, ±12, and ±6V supplies within the unit. If these settings are changed, the unit will have to be recalibrated. If the unit is working correctly, do not adjust the power supply. Remember that the 6 and 12V supplies are dependent on their respective 30V supplies, and the 6V supplies on the 12V supplies. Any adjustment of the 30V supplies will necessitate trimming of the others.
2. START and STOP TURNON. These potentiometers are reachable through the tiny unlabled holes in the tops of the Start and Stop Oscillators. They cannot be adjusted properly without special equipment. Do NOT bother them.
3. COINCIDENCE adjust. This pot is on the coincidence card. It adjusts the bias current through the coincidence tunnel diode. If it is maladjusted, the circuit may produce multiple coincidence pulses or none at all. This control should never be adjusted unless one or more components of the coincidence circuit is replaced.
4. X80 MULTIPLIER controls. These two slug-tuned inductors and two tubular trimmer capacitors adjust the tuned circuits in the X80 multiplier. Normally they need not be adjusted.

5. TEST PULSER. This control, on the test pulser card, adjusts the collector bias of the test pulser output transistor Q2. It will need to be adjusted if and only if Q2 is replaced.
6. TRIGGER ADJUST (A and B). These two potentiometers are mounted under the input attenuators. They adjust the calibration of their respectime Trigger Level controls. They will not need to be adjusted unless one or more components in the discriminator trigger is replaced.
7. DELAY LINES. All the cable lengths in the 796 are critical. Certain of the cables are pruned to length during production test. Cables should never be cut or trimmed. If a cable must for some reason be removed, they must be replaced in their original locations and not interchanged with one another. The 796 will never drift so far out of adjustment that any cables need be trimmed.

5.3.3 On Calibration

The 796 includes only solid state circuitry and is fan cooled to prevent overheating. Its most critical components are enclosed in temperature-controlled ovens. Its internal cables are specially aged for stability and the unit is exhaustively calibrated, tested, and aged before shipment. It will require very little periodic adjustment.

The most frequently required adjustments are the Null potentiometer, the Stop Oscillator potentiometer, and the 1 MHz oscillator. The Start Oscillator is automatically stabilized and will have to be adjusted less often.

Calibration Procedure A, listed below, tells how to adjust Null, Stop, and the 1 MHz oscillator. This procedure should be followed every three months or so, or more often if the 1 MHz setting is very critical to you. Calibration Procedure B tells how to adjust the Start Oscillator and Stabilizer. The checks listed in Procedure B should be performed every six months or so and the adjustments there made if necessary.

The final section lists the functions of certain "fixed" adjustments which might require occasional trimming and certain "fixed" adjustments which should not be molested at any cost.

5.3.4 Calibration Procedure "A"

1. Apply power and allow the instrument to warm up. While the instrument is warming up, gather the following test equipment.

a. An oscilloscope capable of displaying a 1 MHz Lissajous pattern. Calibrated voltage ranges are not necessary.

b. A 1 MHz frequency standard more accurate than the internal oscillator of the Model 796. Be sure of the accuracy of your standard before adjusting the 796 internal oscillator. Check the specification sheet to find the accuracy of your oscillator.

c. An Eldorado Electronics Model 420/421 calibrator.

2. Adjust the internal 1 MHz oscillator. Apply the output of the oscillator connector on the rear panel to the horizontal input of the scope and the output of your standard to the vertical input. Adjust the horizontal and vertical gain and position controls for an elliptic Lissajous pattern. Adjust the internal 1 MHz oscillator for a stable pattern. The more stable oscillators, options D and E, have both coarse and fine frequency adjustments. Usually only the fine adjustment need be touched. Use a plastic alignment tool or well-insulated screwdriver to avoid shorting out the internal circuitry.

   Before adjusting the oscillator, be sure that it has warmed up to stability. Stabilization times are listed in the Specification Tables. After adjusting the oscillator, measure the rotation period of the Lissajous pattern. For the more stable options it should be at least 1000 seconds (15 minutes).

3. Adjust the Null control on the front panel and the Stop Oscillator adjustment on the oscillator chassis. Connect the instrument to a Model 420/421 calibrator as shown in figure 2.3.1. Set the controls as indicated on the diagram. Set the calibrator for 15 ns delay. If the 796 does not read 15 ns, adjust the null pot till it does. Set the calibrator delay to 5 ns. If the 796 does not read 5 ns, remove the top cover and adjust the Stop Oscillator potentiometer till it does. Repeat the procedure with delays of 14 and 4 ns, 13 and 3 ns, 12 and 2 ns, and 11 and 1 ns Then see that the instrument reads correctly for all input delays between 0 and 15 ns. Add the 1/3 ns delay if your calibrator includes one. The unit should still read correctly from 15 to 0 ns. (readings of -90 to 0 ns).

5.3.5 Calibration Procedure "B"

1. Warm the instrument up for at least four hours - - longer if the oscillator ovens have been allowed to cool down - - and perform calibration procedure A in its entirety.

2. The following additional test equipment is required.

   a. A pulse generator to drive the EXT RESET input of the 796 at 8 to 10 kHz. It must produce an output pulse of magnitude -4V or more and a duration of at least 1 μs.

   b. A delay generator such as the Eldorado 610, 615, or 650, to provide the 796 with a calibrated input interval of about 100,000 ns. The interval must be known to ±1 ns. The generator must be triggerable by the TEST PULSE output of the 796.

   If no such generator is available, a less useful substitute is one additional pulse generator. It must be externally triggerable by the TEST PULSE output of the 796 and have an output pulse of duration 100,000 ns ± 10%.

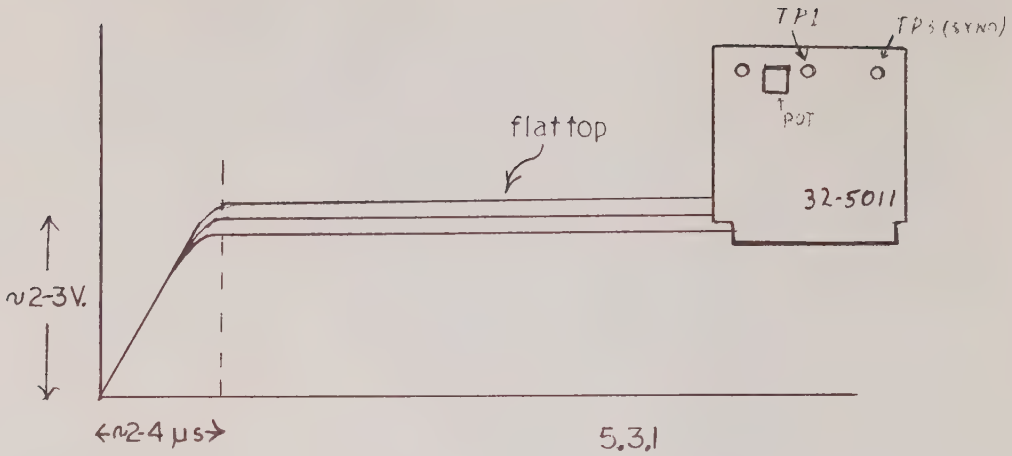
   c. Such BNC cables as are needed to connect the above. The output cables from the delay generator should be of similar cable and of equal length to the nearest inch.

3. If an accurate delay generator is available, check the 796 in the TIM mode by measuring delays of 100, 1000, 10000, and 100,000 ns. If the instrument has more than six decades, apply longer test delays if possible. If the 796 reads accurately to within 1 ns in the first six decades and 2 ns in the longest three, proceed no further. The instrument needs no further calibration. If the instrument is out of calibration, or if no precision delay generator is available, continue with the next step.

4. Connect the 796 to the reset pulse generator and the delay generator or input pulse generator as shown in figure 4.3.1. Adjust the pulse generator so that the 796 is reading and rereading the 100,000 ns interval as quickly as possible.

5. Trigger the oscilloscope from TP3 on the stabilizer card. Trigger on the positive slope. The scope trace now starts coincidentally with the START signal from the discriminator.

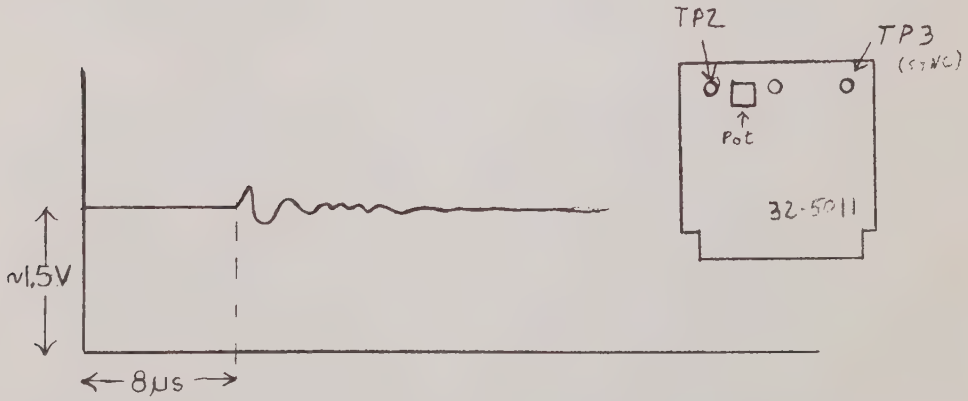
6. Observe the signal at TP1 on the stabilizer. This is the output of the phase detector. This output will start at ground, climb for a microsecond or two, and stay at a DC level till RESET arrives. Each cycle will find and, ideally, stay at, a different DC level. The output at TP1 should look like this:



5.3.1
PHASE DETECTOR OUTPUT

If the top of the curve family is not flat, the oscillator is drifting. Adjust the Freq. Adjust capacitor in the top of the Start Oscillator for a flat-topped set of curves. The adjustment is best accomplished with a long thin fiber alignment tool. A good second choice is a very thin screwdriver insulated with a piece of heat-shrink tubing over its shaft. In any case, bear in mind that the interior of the oscillator is fragile.

7. Observe the signal at TP2 while still triggering the slope from TP3. This signal is the stabilizer VCO output to the Start Oscillator. It should look like this:



5.3.2
STABILIZER OUTPUT

Adjust the Start Potentiometer till the DC levels before and after the switching point are equal. This adjustment is touchy. Then recheck

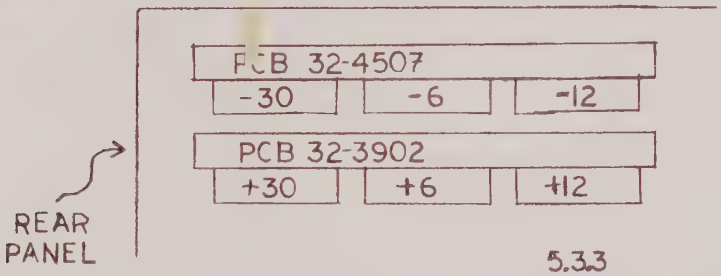
the family of curves at TP1 and readjust the capacitor in the start oscillator if they are no longer flat.

8. Reset the delay generator to produce a 5 ns delay, or use the 420/421 calibrator set to 5 ns. Recheck the family of curves at TP1. If it is not flat on top, trim R68, the trimmer resistor on the stabilizer board, till it is.
9. If you somehow get tangled in the above procedure and can get no reasonable signals at either of the test points, center the Start Potentiometer and start over at step 5. Perform each step slowly and carefully.

5.3.6 Special Adjustments

The remaining trimmers should usually only be adjusted if components associated with them have been replaced. Periodic adjustment of these controls is at best unnecessary and at worst treacherous.

1. POWER SUPPLY ADJUSTMENTS. These six controls adjust the output voltages of the regulator power supplies. Their locations are shown below.



5.3.3
POWER SUPPLY
TRIMMER LOCATIONS

The supply voltages are most readily available for measurement at the power supply terminal block, a Jones strip accessible when the bottom panel is removed. The output voltages should be measured with an accurate digital or differential voltmeter. If the instrument is operating well in all its modes and the supply voltages seem out of spec, by all means leave them as they are. Any readjustment of the power supply will require at least the calibration described in procedure B.

First measure the +30 output (ORN wire). Set it to +30V ±10 mV. Then adjust the +12 supply (GRN) to +12V ±10 mV. Then set the +6V output

(BLU) to +6V ±10 mV. It is important that the controls be adjusted in this order.

Similarly, adjust -30, between -30.00 and -30.010 (ORN/BLK), -12 ±10 mV (GRN/BLK) and -6 ±10 mV (BLU/BLK). Then perform calibration procedure B.

2. START and STOP TURNON potentiometers. These are accessible through the tiny unlabeled holes on the tops of the VCO's. They are correctly adjusted at the factory and should not be touched.
3. COINCIDENCE adjust. This control adjusts the bias current through the coincidence tunnel diode. If this current is set too low, no coincidence pulse will ever be produced. If it is set too high, spurious pulses will appear. The trimmer need not be reset unless a component in the coincidence circuit has been replaced. To adjust the coincidence gate, first set the instrument up as shown in figure 2.3.1. Set the 420 or 421 to 15 ns passive delay and the pulse generator to run the 796 at 8 to 10 kHz. Trigger the scope from TP3 on the stabilizer board and monitor the test point on the coincidence board with a scope rated at 75 MHz or better (Tektronix 581). Adjust the pot for the cleanest positive output from the coincidence card. The pulse should be about 30 ns wide. Any jitter should be on the trailing edge of the pulse.
4. X80 MULTIPLIER controls. These may require occasional adjustment. In any mode, observe the 80 MHz signal at the top of L5. Trim L2, L3, C28, and C29 for maximum output. Then remove cables #8 and #21 from the multiplier-divider board. This makes the output available and starts the divider. Make sure that the output (at J4, where cable #8 was) is 10.000 MHz. If it is some frequency like 7.500 MHz or 15.000 MHz, you have adjusted one or more of the trimmers to the wrong harmonic. Readjust the trimmers for a 10 MHz output. Replace the cables.
5. TEST PULSER. This control will only need to be adjusted if the test pulser output transistor, a type 2N3646, needs to be replaced. Put the 796 in the EXT RESET mode and drive the reset input at about 1 kHz. Adjust the test pulser trimmer so that each reset input produces one and only one test pulse. This pulse should conform to the specifications listed in chapter 1. Several 2N3646 transistors may have to be tested in the circuit before one is found that avalanches properly.

6. TRIGGER ADJUST. These adjustments will have to be reset if any component in the discriminator trigger is replaced.

   Remove the bottom panel and place the unit on its side to make the adjustments accessible. Turn both adjustments to their maximum.

   Set both input attenuators at unity and both front panel trigger level controls at 1V. Set both slope controls to positive (+) and both polarity controls to positive (+). Set the mode to TIM and Display mode to Direct.

   Apply a DC level of 1V ±0.1V to the A input only. Carefully turn the A trigger adjust control down till the unit just starts counting. Connect the DC level to the B input. Turn the B adjust down till the counter just stops. Disconnect the DC level and reset the counter manually. Turn the DC supply down to about 0.5V and reconnect it to the A input. Turn it up slowly till the counter just starts, and verify that the DC level is 1V ±.05V. If not, turn the input voltage down, reset the counter, adjust the A pot a tiny bit, and increase the input voltage again. Repeat the adjustment till the 1V trigger is accurate. Do the same for the B trigger adjust.

7. DELAY LINES. The fixed delays in the Model 796 are carefully trimmed lengths of RG188-U coaxial cable specially aged and tested. Never interchange interconnecting cables even if they seem to fit. Never attempt to adjust any delay cable. They are cut to length in the factory and should not be touched by untrained personnel.

CHAPTER 6

PARTS LIST

CHAPTER 6

PARTS LIST

6.1 INTRODUCTION

This chapter includes the information necessary to identify any electrical part of the Model 796 and to order the part if it be necessary.

To use the parts list, first find the page listing the parts for the particular sub-assembly in question (Multiplier Card, Front Panel, etc.). Then find the component number on the left-hand edge of the page. The component is described fully and at least one identifying number is given for each.

6.2 ORDERING INFORMATION

Most small components are available from local distributors more quickly and economically than from Eldorado. Many specialized components, however, are available only from this factory. To order parts from Eldorado, address:

Customer Service Parts Department
Eldorado Electronics
601 Chalomar Road
Concord, California 94520
Telephone: 415-686-4200
TWX: 910-481-9476

When ordering, give the following information for each part:

1. Instrument model and serial number
2. Sub-assembly name and number
3. Component number
4. Any applicable parts number
5. Description (viz. "470 ohm, 1W, 5%, carbon resistor")

6.3 CODE LIST OF MANUFACTURERS

In the parts lists, each manufacturer is identified by a two-, three-, or four-letter code.

The following table lists the full names and addresses of the manufacturers. In some cases it may be best to buy components directly from them.

AB	Allen-Bradley Co., Milwaukee, Wisconsin
AERO	Aerovox Corp., New Bedford, Massachusetts
AML	Amphenol Electronics Corp., Chicago, Illinois
AMPE	Amperex Electronics Corp., Hauppauge, New York
AUG	Augat Inc., Attleboro, Massachusetts
BECK	Beckman Instruments, Helipot Div., Fullerton, California
BUCK	Buckeye Stamping Co., Columbus, Ohio
BUR	Burroughs Corp., Philadelphia, Pennsylvania
CAM	Cambridge Thermionic Corp., Cambridge, Massachusetts
CDC	Continental Device Corp., Hawthorne, California
CK	C & K Components, Inc., Watertown, Massachusetts
CLAR	Clarostat Mfg. Co., Inc., Dover, New Hampshire
CRL	Centralab, Milwaukee, Wisconsin
CTS	Chicago Telephone Supply, Elkart, Indiana
DEL	Delevan Electronics Corp., Aurora, New York
EE	Eldorado Electronics, Concord, California
ELC	ELCO Corp., Philadelphia, Pennsylvania
ERR	Erie Technological Products, Erie, Pennsylvania
FAI	Fairchild Semiconductor, Mountain View, California
FER	Ferroxcube Corp., Saugerties, New York
GE	General Electric Co., Auburn, New York
HET	Hetherington, Sharon Hill, Pennsylvania
HOW	Howard Ind., Racine, Wisconsin
IDC	International Diode Corp., Jersey City, New Jersey
IRC	IRC, Boone, North Carolina
ITT	ITT Semiconductors, West Palm Beach, Florida
JFD	J.F.D. Electronics Corp., Brooklyn, New York
MOT	Motorola, Phoenix, Arizona
OHM	Ohmite Mfg. Co., Skokie, Illinois
OK	Oak Mfg., Crystal Lake, Illinois
PHIL	Philadelphia Handle, Camden, New Jersey
PLC	Philco, Lansdale, Pennsylvania
RAY	Raytheon Corp., Waltham, Massachusetts
RCA	RCA, Harrison, New Jersey
SAN	Sangamo Electric Co., Springfield, Illinois
SEA	Sealectro, Mamaroneck, New York
SEM	Semtech Corp., Newbury, California
SIE	Siemens America Inc., White Plains, New York
SMH	H.H. Smith, Brooklyn, New York
SOL	Solitron Devices, Riviera Beach, Florida
SPR	Sprague Electric, North Adams, Massachusetts
TI	Texas Instruments, Dallas, Texas
TRX	Tranex, Mountain View, California

Discriminator (D-32-04814) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1, 9, 10, 14, 21, 22, 23, 25, 26, 28, 29, 31, 32, 34, 36	Capacitor, disc ceramic, .001 μF	AERO	SSD	C00750	15
C2, 3, 11, 12	Capacitor, dipped mica 100 pF, 500 V	SAN	D155F101JO	C00460	4
C4, 8, 13, 17, 18, 30, 33, 35, 37	Capacitor, Mylar 0.1 μF, 250 V	AMPE	C280AE/P100K	C01304	9
C5, 15, 27	Capacitor, dipped mica 56 pF, 500 V	SAN	D155F560JO	C00400	3
C6	Capacitor, disc ceramic .01 μF, 100 V	SPR	TGS-10	C01000	1
C7, 16	Capacitor, dipped mica 1000 pF, 100 V	SAN	D151F102JO	C00710	2
C19	Capacitor, disc ceramic .005 μF, 100 V	SPR	TG-D50	C00960	1
C24	Capacitor, dipped mica 560 pF	SAN	D155F561JO	C00670	1
CR1, 4, 11, 12, 48	Diode	IDC	Q6-100	D01050	5
CR2, 3, 13, 14	Diode, tunnel	GE	TD252	D01450	4
CR5-10, 15-42, 45-47, 49	Diode	CDC	CD6767	D00600	38
CR43, 44, 50	Diode, tunnel	GE	TD253	D01460	3
J1-9	Connector, min coax	SEA	51-051-0000	C03240	9
L1, 2	Ferrite bead	FER	56-590-6513-B	T00800	2
Q1, 2, 7, 8, 15, 16, 23, 27, 30, 31	Transistor	FAI	2N3640	T04090	10
Q3, 4, 7, 11, 20	Transistor	FAI (ONLY)	2N709	T03290	5
Q5, 6, 9, 12, 13, 14, 17, 18, 19, 21, 24, 25, 26, 29, 32, 33, 34	Transistor	FAI	2N3646	T04135	17
Q22, 28	Transistor	TI	2N3702	T04160	2

Discriminator (D-32-04814) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R1, 2	Resistor, carbon 2.2k, 1/2W, 5%	AB		R02305	2
R3, 4, 8, 9, 29, 30, 33, 34, 71, 75, 79, 97, 108, 109, 110	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	15
R5, 6, 31, 32	Resistor, carbon 10Ω, 1/4W 5%	AB		R01515	4
R7, 11, 39, 40 77, 107	Resistor, carbon 51Ω, 1/4W, 5%	AB		R01560	6
R10, 12, 13, 38, 41, 42	Resistor, metal film 100Ω, 1/2W, 1%	IRC	CEBT0		6
R14, 15, 18 35, 43, 51-54, 64	Resistor, carbon 3k, 1/2W, 5%	AB	EM		11
R16, 19, 27, 28, 36, 62, 78, 83, 85, 92, 93, 104	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	12
R17, 20, 37	Resistor, carbon 270Ω, 1/4W, 5%	AB		R01620	3
R21, 24, 60, 44-50, 89	Resistor, carbon 10k, 1/4W, 5%	AB		R01755	11
R22, 23	Resistor, carbon 1.5k, 1W, 5%	AB		R02980	2
R25, 26, 64, 68, 76, 84, 90, 95, 103, 111, 113	Resistor, carbon 560Ω, 1/4W, 5%	AB		R01650	11
R56, 67, 112	Resistor, carbon 27Ω, 1/4W, 5%	AB		R01540	3
R57, 100	Resistor, carbon 1.2k, 1/4W, 5%	AB		R01675	2
R58, 70, 96, 106	Resistor, carbon 220Ω, 1/4W, 5%	AB		R01610	4
R59	Resistor, carbon 3.3k, 1/4W, 5%	AB		R01715	1
R63	Not used				
R65	Resistor, carbon 4.3k, 1/4W, 5%	AB	EB		1
R66	Resistor, carbon 1k, 1W, 5%	AB		R02975	1

Discriminator (D-32-04814) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R69,101	Resistor, carbon 56Ω, 1/2W, 5%	AB		R02175	2
R72	Resistor, carbon 820Ω, 1/4W, 5%	AB		R01665	1
R73	Resistor, carbon 4.7k, 1/4W, 5%	AB		R01725	1
R74	Resistor, carbon 470Ω, 1/4W, 5%	AB		R01640	1
R80	Resistor, carbon 120Ω, 1/2W, 5%	AB		R02205	1
R81	Resistor, carbon 56Ω, 1/4W, 5%	AB		R01565	2
R82,87,102	Resistor, carbon 5.6k, 1/4W, 5%	AB		R01735	3
R86	Resistor, carbon 8.2k, 1/4W, 5%	AB		R01750	1
R91,94	Resistor, carbon 15k, 1/4W, 5%	AB		R01765	2
R98	Resistor, carbon 100k, 1/4W, 5%	AB		R01830	1
R99	Resistor, carbon 2.7k, 1/2W, 5%	AB		R02310	1
R105	Resistor, carbon 150Ω, 1/4W, 5%	AB		R01595	1
R114	Resistor, carbon 1.2k, 1W, 5%	AB		R02975	1

Logic (A-32-4804) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1, 12	Capacitor, disc ceramic, .01 μF, 100 V	SPR	TGS-10	C01000	2
C2, 18, 19, 20	Capacitor, dipped mica 270 pF, 500 V	SAN	D155F271JO	C00560	4
C3, 5, 10, 11, 15, 16	Capacitor, disc ceramic, .001 μF	SAN		C00740	6
C4	Not used				
C6, 14	Capacitor, dipped mica 330 pF, 500 V	SAN	D155F331JO	C00600	2
C7, 8	Capacitor, dipped mica 680 pF, 500 V	SAN			2
C9	Capacitor, Mylar 0.1 μF, 250 V	AMPE	C280AE/P100K	C01304	1
C13	Capacitor, Mylar .0047 μF, 50 V, 5%	GE	65F10AC472	C00920	1
C17	Capacitor, electrolytic 3 μF, 12 V	SPR	TE1122		1
CR1-13	Diode, silicon	CDC	CD6267 ~	D00600	13
Q1-7, 11, 14, 15, 19, 22-25	Transistor	TI	2N3702	T04160	15
Q8, 9, 10, 12, 13, 16, 17, 18, 21, 26, 27	Transistor	FAI	2N3646	T04135	11
Q20	Transistor, unijunction	TI	TIS43	T05075	1
R1, 5, 6, 22, 48, 53, 57, 89	Resistor, carbon 5.6k, 1/4W, 5%	AB		R01735	8
R2, 15, 27, 30, 34, 35, 45, 49, 62, 66	Resistor, carbon 10k, 1/4W, 5%	AB		R01755	10
R3, 10, 21, 33, 55, 56, 88	Resistor, carbon 3.3k, 1/4W, 5%	AB		R01715	7
R4, 8, 12, 58, 68, 80	Resistor, carbon 3.9k, 1/4W, 5%	AB		R01720	6
R7	Resistor, carbon 1.8k, 1/4W, 5%	AB		R01685	1
R9, 11, 13, 25 32, 52, 69, 74, 78, 87	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	10
R14, 71, 72	Resistor, carbon 68k, 1/4W, 5%	AB		R01810	3

Logic (A-32-4804) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R16, 24	Resistor, carbon 680Ω, 1/4W, 5%	AB		R01660	2
R17, 23, 75	Resistor, carbon 4.7k, 1/4W, 5%	AB		R01725	3
R18, 19	Resistor, carbon 120k, 1/4W, 5%	AB		R01835	2
R20, 67, 70, 73, 76, 77, 86	Resistor, carbon 6.8k, 1/4W, 5%	AB		R01740	7
R26, 82	Resistor, carbon 2.2k, 1/4W, 5%	AB		R01695	2
R28, 65	Resistor, carbon 10Ω, 1/4W, 5%	AB		R01515	2
R31, 43	Resistor, carbon 820Ω, 1/4W, 5%	AB		R01665	2
R29	Resistor, carbon 10M, 1/4W, 5%	AB		R01930	1
R36	Resistor, carbon 12k, 1/4W, 5%	AB		R01760	1
R37, 38, 47	Resistor, carbon 1.2k, 1/4W, 5%	AB		R01675	3
R39	Resistor, carbon 2.7k, 1/4W, 5%	AB		R01705	1
R40, 90	Resistor, carbon 47k, 1/4W, 5%	AB		R01795	2
R41, 79, 81	Resistor, carbon 27k, 1/4W, 5%	AB		R01780	3
R42	Resistor, carbon 47Ω, 1/4W, 5%	AB		R01540	1
R44	Resistor, carbon 2.2k, 1/2W, 5%	AB		R02305	1
R46	Resistor, carbon 390Ω, 1/4W, 5%	AB		R01635	1
R50, 61	Resistor, carbon 100k, 1/4W, 5%	AB		R01830	2
R51, 85	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	2
R54	Resistor, carbon 1.5k, 1/4W, 5%	AB		R01680	1
R55	Resistor, carbon 56k, 1/4W, 5%	AB		R01800	1

Logic (A-32-4804) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R60	Resistor, carbon 33k, 1/4W, 5%	AB		R01785	1
R63, 64	Resistor, carbon 560Ω, 1/4W, 5%	AB		R01650	2
R83, 84, 91	Resistor, carbon 22k, 1/4W, 5%	AB		R01775	3

25 MHz DCU (D-32-03968) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1, 2, 19, 20	Capacitor, Mylar .1 μF, 250 V	AMPE	C280AE/P100K	C01304	4
C3, 4	Capacitor, dipped mica 33 pF, 500 V	SAN	D155F330JO	C00320	2
C5, 6	Capacitor, dipped mica 15 pF, 500 V	SAN	D155F150JO	C00202	2
C7, 8, 11, 12, 15	Capacitor, dipped mica 27 pF, 500 V	SAN	D155F270JO	C00300	5
C9, 10	Capacitor, dipped mica 22 pF, 500 V	SAN	D155F220JO	C00270	2
C13, 14, 16, 17, 18	Capacitor, dipped mica 39 pF, 500 V	SAN	D155F390JO	C00330	5
CR1-23, 25-32	Diode, silicon	CDC	CD6267	D00600	31
CR24	Not used				
L1	Ferrite bead	FER	56-590-65/3B	T00800	1
Q1-10	Transistor	FAI	2N3640	T04090	10
R1, 7, 15, 23, 27, 36, 40, 45	Resistor, carbon 68k, 1/4W, 5%	AB		R01810	8
R2, 8, 16, 17, 28, 29, 41, 46, 52, 56	Resistor, carbon	AB		R01755	10
R3, 11, 19, 22, 47	Resistor, carbon 18k, 1/4W, 5%	AB		R01770	5
R4, 10, 42, 48	Resistor, carbon 4.7k, 1/4W, 5%	AB		R01725	4
R5, 12	Resistor, carbon 510Ω, 1/4W, 5%	AB		R01645	2
R6, 13, 21, 26, 34, 39, 44, 50	Resistor, carbon 270Ω, 1/4W, 5%	AB		R01620	8
R9, 33, 38	Resistor, carbon 820Ω, 1/4W, 5%	AB		R01665	3
R14, 32, 51, 53	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	4
R18, 24	Resistor, carbon 5.6k, 1/4W, 5%	AB		R01735	2
R20, 25, 43, 49	Resistor, carbon 680Ω, 1/4W, 5%	AB		R01660	4

25 MHz DCU (D-32-03968) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R30, 37	Resistor, carbon 6.8k, 1/4W, 5%	AB		R01740	2
R31, 35	Resistor, carbon 1.2k, 1/4W, 5%	AB		R01675	2

2.5 MHz DCU (D-32-03967) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty
C1, 2, 19, 20	Capacitor, Mylar .1 μF, 250 V	AMPE	C280AE/P100K	C01304	4
C3, 4	Capacitor, dipped mica 33 pF, 500 V	SAN	D155F330JO	C00320	2
C5, 6, 16, 17	Capacitor, dipped mica 27 pF, 500 V	SAN	D155F270JO	C00300	4
C7, 8, 15, 18	Capaictor, dipped mica 47 pF, 500 V	SAN	D155F470JO	C00360	4
C9, 10, 13, 14	Capacitor, dipped mica 39 pF, 500 V	SAN	D155F390JO	C00330	4
C11, 12	Capacitor, dipped mica 68 pF, 500 V	SAN	D155F680JO	C00410	2
CR1, 2, 5, 6, 8, 10, 14, 18, 21, 25, 28, 30, 31, 32	Diode, silicon	CDC	CD6267	D00600	14
Other CR	Not used				
L1	Ferrite bead	FER	56-590-65/3B	T00800	1
Q1-8	Transistor	FAI	2N3640	T04090	8
Q9	Transistor	TI	2N3702	T04160	1
R1, 7, 15, 23, 27, 36, 40, 45	Resistor, carbon 68k, 1/4W, 5%	AB		R01810	8
R2, 8, 16, 17, 28, 29, 41, 46, 53	Resistor, carbon 10k, 1/4W, 5%	AB		R01755	9
R3, 11	Resistor, carbon 1.8k, 1/4W, 5%	AB		R01685	2
R4, 10, 42, 47, 48	Resistor, carbon 6.8k, 1/4W, 5%	AB		R01740	5
R5	Resistor, carbon 1.5k, 1/4W, 5%	AB		R01680	1
R6, 13, 21, 26, 34, 39, 44, 50	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	8
R12, 20, 25, 33, 38, 43, 49, 51	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	8
R14	Resistor, carbon 2.7k, 1/4W, 5%	AB		R01705	1
R18, 24, 30, 37	Resistor, carbon 4.7k, 1/4W, 5%	AB		R01725	4

2.5 MHz DCU (D-32-03967) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R19,22	Resistor, carbon 3.3k, 1/4W, 5%	AB		R01715	2
R31,35	Resistor, carbon 5.6k, 1/4W, 5%	AB		R01735	2
R52	Resistor, carbon 39k, 1/4W, 5%	AB		R01790	1
R54,55,56, 57,58,59	Resistor, carbon 3.9k, 1/4W, 5%	AB		R01720	6

250 kHz DCU (D-32-03966) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1, 2, 19, 20	Capacitor, Mylar .1 μF, 250 V	AMPE	C280AE/P100K	C01304	4
C3, 4, 18	Capacitor, dipped mica, 220 pF, 500 V	SAN	D155F221JO	C00550	3
C5, 6, 16, 17	Capacitor, dipped mica, 270 pF, 500 V	SAN	D155F271JO	C00560	4
C7, 8, 15	Capacitor, dipped mica, 470 pF, 500 V	SAN	D155F471JO	C00650	3
C9, 10, 13, 14	Capacitor, dipped mica, 390 pF, 500 V	SAN	D155F390JO	C00640	4
C11, 12	Capacitor, dipped mica, 680 pF, 500 V	SAN	D155F681JO	C00680	2
CR1, 2, 5, 6, 8, 10, 14, 18, 21, 25, 28	Diode, silicon	EE	3-1001	D09000	14
L1	Ferrite bead	FER	56-590-65/3B	T00800	1
Q1-8	Transistor	TI	2N3702	T04160	8
R1, 7, 15, 23, 27, 36, 40, 45	Resistor, carbon 68k, 1/4W, 5%	AB		R01810	8
R2, 8	Resistor, carbon 4.7k, 1/4W, 5%	AB		R01725	2
R3, 11, 14	Resistor, carbon 2.7k, 1/4W, 5%	AB		R01705	3
R4, 10	Resistor, carbon 6.8k, 1/4W, 5%	AB		R01740	2
R5	Resistor, carbon 1.5k, 1/4W, 5%	AB		R01680	1
R6, 13, 21, 26, 34, 39, 44, 50	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	8
R12, 20, 25, 33, 38, 39, 43	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	7
R16, 17, 18, 24, 28, 29, 30, 37, 41, 42, 46, 48, 53	Resistor, carbon 10k, 1/4W, 5%	AB		R01755	13
R19, 22	Resistor, carbon 3.3k, 1/4W, 5%	AB		R01715	2
R31, 35	Resistor, carbon 5.6k, 1/4W, 5%	AB		R01735	2

250 kHz DCU (D-32-03966) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R47	Resistor, carbon 15k, 1/4W, 5%	AB		R01765	1
R52	Resistor, carbon 39k, 1/4W, 5%	AB		R01790	1
R54-59	Resistor, carbon 3.9k, 1/4W, 5%	AB		R01720	6

Memory Readout (D-32-04962) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
CR1	Diode, silicon	EE	3-1001	D09000	1
CR2, 3	Diode, zener	EE	3-1005 (1N749A)	D09040	2
Q1-8, 20	Transistor	EE	4-1002	T08010	9
Q9-18	Transistor, neon driver	EE	4-1001	T08000	10
Q19	Transistor	GE	2N2712	T03890	1
R1, 6, 11, 14, 19, 22, 27, 30, 35	Resistor, carbon 22k, 1/4W, 5%	AB		R01775	9
R2	Resistor, carbon 47k, 1/4W, 5%	AB		R01795	1
R3	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	1
R4	Resistor, carbon 150Ω, 1/4W, 5%	AB		R01595	1
R5	Not used				
R7, 12, 15, 20, 23, 31, 36, 50	Resistor, carbon 33k, 1/4W, 5%	AB		R01785	8
R8, 9	Resistor, carbon 1.8k, 1/4W, 5%	AB		R01685	2
R13, 18, 21, 26, 28, 34	Resistor, carbon 6.8k, 1/4W, 5%	AB		R01775	6
R16, 17, 24, 25, 32, 33, 57	Resistor, carbon 2.7k, 1/4W, 5%	AB		R01705	7
R37	Resistor, carbon 82k, 2W, 5%	AB		R03540	1
R38-45	Resistor, carbon 27k, 1/4W, 5%	AB		R01780	8
R46	Resistor, carbon 12k, 1/4W, 5%	AB		R01760	1
R51, 52, 53, 54, 56	Resistor, carbon 15k, 1/4W, 5%	AB		R01765	5
R55	Resistor, carbon 220k, 1/4W, 5%	AB		R01855	1

Test Pulser (A-32-04945) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1	Capacitor, disc, .001 μF, 50 V	AERO	SSD	C00750	1
C2, 3	Capacitor, disc, .47 μF, 25 V	SPR	5C11	C01400	2
C4, 7	Capacitor, disc, .01 μF, 100 V	SPR	TGS-10	C01000	1
C5	Capacitor, dipped mica, 330 pF, 500 V	SAN	D155F331JO	C00600	1
C6, 11	Capacitor, dipped mica, 1000 pF, 100 V	SAN	D151F102JO	C00710	2
C8	Capacitor, dipped mica, 470 pF, 500 V	SAN	D155F471JO	C00650	1
C9	Capacitor, electrolytic 8 μF, 350 V	SPR	TVA1603	C01570	1
C10	Capacitor, dipped mica 82 pF, 500 V	SAN	D155F820JO	C00440	1
CR1, 2	Diode	CDC	CD-6267	D00600	2
CR3	Diode, zener	MOT	1N3044B	D04890	1
J1, 2	Connector	SEA	51-054-0000	C03200	2
L1	Inductor	EE		A-45-04832	1
Q1, 2	Transistor	EE	4-1002	T08010	2
Q3	Transistor	PLC	2N2048	T03720	1
Q4	Transistor	GE	2N3646	T04135	1
R1	Resistor, carbon 10Ω, 1/4W, 5%	AB		R01515	1
R2	Resistor, carbon 4.7Ω, 1/4W, 5%	AB		R01510	1
R3	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	1
R4, 22	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	2
R5	Resistor, carbon 10k, 1/4W, 5%	AB		R01755	1
R6, 7	Resistor, carbon 330Ω, 1/4W, 5%	AB		R01630	2
R8	Resistor, carbon 22k, 1/4W, 5%	AB		R01775	1
R9	Resistor, carbon 4.7k, 1/4W, 5%	AB		R01725	1
R10	Resistor, carbon 8.2k, 1/4W, 5%	AB		R01750	1

Test Pulser (A-32-04945) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R11, 14	Resistor, carbon 5.6k, 1/4W, 5%	AB		R01735	2
R12	Resistor, carbon 3.3k, 1/4W, 5%	AB		R01715	1
R13	Resistor, carbon 470Ω, 1/4W, 5%	AB		R01640	1
R15	Resistor, carbon 27k, 1W, 5%	AB		R03070	1
R16, 17	Resistor, carbon 10k, 1/2W, 5%	AB		R02730	2
R18	Potentiometer, Min. WW, 25k, 1/2W, 5%	OHM	AS3608	P03200	1
R19	Resistor, carbon 82Ω, 1/2W, 5%	AB		R02190	1
R20, 21	Resistor, carbon 27Ω, 1/4W, 5%	AB		R01540	2

Coincidence Circuit (32-04803) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1, 4, 6	Capacitor, disc ceramic, .01 μF	CRL	OD103	C01070	3
C2, 7	Capacitor, Mylar 0.1 μF, 250 V	AMPE	C280AE/P100K	C01304	2
C3	Capacitor, dipped mica, 47 pF, 500 V	SAN	D155F470JO	C00360	1
C5	Capacitor, dipped mica, 22 pF, 500 V	SAN	D155F220JO	C00270	1
CR1, 3	Diode, tunnel	GE	TD253A	D01470	2
CR2	Diode, tunnel	GE	TD252	D01460	1
Delay Lines	Coax cable, total length 2", trimmed length 1.8" ±.05"	AML	RG-188/U		2
J1, 2, 3	Connector, coax	SEA	51-051-0000	C03240	3
L1	Inductor, ferrite core, 1.8 μH	DEL	1025-26	I 02460	1
Q1	Transistor	FAI	2N709	T03290	1
Q2	Transistor	FAI	2N3640	T04090	1
R1, 12	Resistor, carbon 33Ω, 1/8W, 5%	AB		R01050	2
R2, 4, 7, 11	Resistor, carbon, 33Ω, 1/4W, 5%	AB		R01545	4
R3	Resistor, carbon 3.3Ω, 1/4W, 5%	AB		R01505	1
R5, 9, 10, 15	Resistor, carbon 390Ω, 1/4W, 5%	AB		R01635	4
R6	Pot, subminiature, 100Ω	BECK	62PAR100	P01205	1
R8	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	1
R13	Resistor, carbon 4.7k, 1/4W, 5%	AB		R01725	1
R14	Resistor, carbon 4.9k, 1/4W, 5%	AB		R01720	1
R16, 17	Resistor, carbon 51Ω, 1/4W, 5%	AB		R01560	2

Stop Circuit (D-32-04943) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1	Capacitor, dipped mica, 120 pF, 500 V	SAN	D155F121JO	C00480	1
C2, 5, 7, 8	Capacitor, dipped mica, 39 pF, 500 V	SAN	D155F390JO	C00330	4
C3, 13, 14	Capacitor, disc, .1 μF, 25 V	SPR	5CF		3
C4	Capacitor, dipped mica, 180 pF, 500 V	SAN	D155F181JO	C00530	1
C6	Capacitor, disc, .47 μF, 25V	SPR	5C11	C01400	1
C9	Capacitor, dipped mica, 33 pF, 500 V	SAN	D155F330JO	C00320	1
C10, 11	Capacitor, dipped mica, 47 pF, 500 V	SAN	D155F470JO	C00360	2
C12	Not used				
CR1, 3, 4, 5, 6	Diode, silicon	CDC	CD6267	D00600	5
CR2	Not used				
J1, 2, 3	Connector, coax	SEA	51-045-0000	C03200	3
Q1-7	Transistor	TI	2N711B	T08020	7
R1	Resistor, carbon 4.7Ω, 1/2W, 5%	AB		R02210	1
R2	Resistor, carbon 10Ω, 1/2W, 5%	AB		R02115	1
R3	Not used				
R4, 9	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	2
R5, 10, 12, 16	Resistor, carbon 1.2k, 1/4W, 5%	AB		R01675	4
R6, 11, 13, 17	Resistor, carbon 4.7k, 1/4W, 5%	AB		R01725	4
R7, 8, 14, 15	Resistor, carbon 220Ω, 1/4W, 5%	AB		R01610	4
R18, 22	Resistor, carbon 470Ω, 1/4W, 5%	AB		R01640	2
R19, 20	Resistor, carbon 47Ω, 1/4W, 5%	AB		R01555	2
R21	Resistor, carbon 270Ω, 1/4W, 5%	AB		R01620	1
R23, 25	Resistor, carbon 1.5k, 1/4W, 5%	AB		R01680	2
R24	Resistor, carbon 6.8k, 1/4W, 5%	AB		R01740	1

Stop Circuit (D-32-04943) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R26	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	1
R27	Resistor, carbon 56Ω, 1/4W, 5%	AB		R01565	1
R28	Resistor, carbon 5.6k, 1/4W, 5%	AB		R01735	1
R30, 31	Resistor, carbon 10Ω, 1/4W, 5%	AB		R01515	2

Add One Circuit (D-32-04948) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1	Capacitor, dipped mica, 180 pF, 500 V	SAN	D155F181JO	C00530	1
C2, 4, 13-16	Capacitor, dipped mica, 33 pF, 500 V	SAN	D155F330JO	C00320	6
C3, 5, 6, 7, 17	Capacitor, dipped mica, 47 pF, 500 V	SAN	D155F470JO	C00360	5
C8	Capacitor, dipped mica, 68 pF, 500 V	SAN	D155F680JO	C00410	1
C9, 11	Capacitor, paper 2.2 μF, 25 V	SPR	5C15	C01540	2
C10	Capacitor, Mylar 0.1 μF, 250 V	AMPE	C280AE/P100K	C01304	1
C12	Capacitor, dipped mica 56 pF, 500 V	SAN	D155F560JO	C00400	1
CR1-9	Diode, silicon	CDC	CD6267	C00600	9
J1-3	Connector	SEA	51-051-0000	C03240	3
L1-3	Choke, 2.2 μH	DEL	1025-28	I 02480	3
Q1-6, 15-18	Transistor, PNP	EE	4-1003	T08020	10
Q7-11	Transistor, PNP	FAI	2N3640	T04100	5
Q12-14	Transistor, NPN	FAI	2N3646	T04135	3
R1, 4, 12, 21, 27, 32, 39	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	7
R2, 9, 13, 14, 49	Resistor, carbon 220Ω, 1/4W, 5%	AB		R01610	5
R3, 20, 33	Resistor, carbon 3.9k, 1/4W, 5%	AB		R01720	3
R5, 19	Resistor, carbon 680Ω, 1/4W, 5%	AB		R01660	2
R6, 7, 11	Resistor, carbon 5.6k, 1/4W, 5%	AB		R01735	3
R8, 50	Resistor, carbon 1.5k, 1/4W, 5%	AB		R01680	2
R10, 16	Resistor, carbon 68Ω, 1/4W, 5%	AB		R01575	2
R15	Resistor, carbon 1.2k, 1/4W, 5%	AB		R01675	1
R17	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	1
R18	Not used				

Add One Circuit (D-32-04948) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R22, 23	Resistor, carbon 10Ω, 1/2W, 5%	AB		R01215	1
R24, 25, 30, 31, 38, 40	Resistor, carbon 6.8k, 1/4W, 5%	AB		R01740	6
R26	Resistor, carbon 10k, 1/4W, 5%	AB		R01755	1
R28, 29	Resistor, carbon 33k, 1/4W, 5%	AB		R01785	2
R34, 35, 48	Resistor, carbon 27k, 1/4W, 5%	AB		R01705	3
R36, 37, 41	Resistor, carbon 3.3k, 1/4W, 5%	AB		R01715	3
R42	Resistor, carbon 330Ω, 1/4W, 5%	AB		R01630	1
R43, 45	Resistor, carbon 1.8k, 1/4W, 5%	AB		R01685	2
R44, 46	Resistor, carbon 4.7k, 1/4W, 5%	AB		R01725	2
R47	Resistor, carbon 8.2k, 1/4W, 5%	AB		R01750	1

Stabilizer (32-5017) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1, 12, 20	Capacitor, dipped mica, 220 pF, 500 V	SAN	D155F221JO	C00550	3
C2-7, 9, 10, 18, 22, 34	Capacitor, disc, .01 μF, 100 V	SPR	TGS-10	C01000	11
C8	Capacitor, Mylar .0047 μF, 50 V, 5%	GE	65F10AC47C	C00920	1
C11, 13, 15, 16, 24	Capacitor, dipped mica, 100 pF, 500 V	SAN	D155F101JO	C00460	5
C19	Not used				
C21	Capacitor, dipped mica 56 pF, 500 V	SAN	D155F560JO	C00400	1
C23-25	Not used				
C26, 28, 32, 39	Capacitor, disc ceramic, .001 μF	AERO	SSD	C00750	4
C27, 29, 31, 33	Capacitor, Mylar 0.1 μF, 250 V	AMPE	C280AE/P100K	C01304	4
CR1	Diode	FAI	FD777	D00760	1
CR2-4, 7-23	Diode	MOT	1N4152	D06420	20
CR5, 6	Diode	FAI	FD300		2
J1, 2, 3	Connector, min. coax	SEA	50-051-0000	C03240	3
L1	Inductor Ferrite 240 μH	DEL	1537-9	I04060	1
Q1, 2, 4, 5, 6, 12	Transistor	FAI	2N3646	T04135	6
Q3, 15, 16	Not used				
Q7, 9, 10, 11, 13, 14, 16, 17	Transistor	FAI	2N3640	T04090	8
Q8	Transistor, FET	MOT	2N4221	T04230	1
R1, 2	Resistor, carbon 51Ω, 1/4W, 5%	AB		R01560	2
R3, 4	Resistor, carbon 56Ω, 1/4W, 5%	AB		R01565	2
R5, 6, 33, 48, 49, 50, 52, 55, 59, 62, 63, 64, 66	Not used				
R7, 30, 56, 57, 69, 70,	Resistor, carbon 5.6k, 1/4W, 5%	AB		R01735	6
R8, 17	Resistor, carbon 1.8k, 1/4W, 5%	AB		R01685	2

Stabilizer (32-5017) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R9, 11, 12, 16, 22, 25, 28	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	7
R10, 47	Resistor, carbon 12k, 1/4W, 5%	AB		R01760	2
R13, 21, 38, 44	Resistor, carbon 8.2k, 1/4W, 5%	AB		R01750	4
R14, 15	Resistor, carbon 10Ω, 1/4W, 5%	AB		R01515	2
R18, 19, 24	Resistor, carbon 6.8k, 1/4W, 5%	AB		R01740	3
R20, 58, 60, 71	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	4
R23	Resistor, carbon 47Ω, 1/4W, 5%	AB		R01555	1
R26, 32, 37, 40	Resistor, carbon 3.9k, 1/4W, 5%	AB		R01720	4
R27, 31, 66	Resistor, carbon 27Ω, 1/4W, 5%	AB		R01540	3
R29, 51	Resistor, carbon 22Ω, 1/4W, 5%	AB		R01535	2
R34, 35, 61, 65	Resistor, carbon 4.7k, 1/4W, 5%	AB		R01725	4
R39, 53, 54	Resistor, carbon 2.7k, 1/4W, 5%	AB		R01705	3
R41	Resistor, carbon 10k, 1/4W, 5%	AB		R01755	1
R42	Resistor, carbon 2.2k, 1/4W, 5%	AB		R01695	1
R43	Resistor, carbon 22k, 1/4W, 5%	AB		R01775	1
R45	Resistor, carbon 1.2k, 1/4W, 5%	AB		R01675	1
R46	Resistor, carbon 47k, 1/4W, 5%	AB		R01795	1
R67	Resistor, carbon 220Ω, 1/4W, 5%	AB		R01610	1
R68	Potentiometer 100Ω	BECK	62PAR100	P01205	1

Multiplier-Divider (32-5211) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1, 15, 19, 32, 34	Capacitor, disc ceramic, .001 μF	AERO	SSD	C00750	5
C2, 5, 6, 11, 37	Capacitor, disc ceramic, .01 μF, 100 V	SPR	TGS-10	C01000	5
C3, 4, 25, 26, 27	Not used				
C7	Capacitor, dipped mica, 100 pF, 500 V	SAN	D155F101JO	C00460	1
C8, 35	Capacitor, Mylar 0.1 μF, 250 V	AMPE	C280AE/P100K	C01304	2
C9	Capacitor, disc, .05 μF, 50 V	CRL	CK503	C01201	1
C10, 17	Capacitor, dipped mica, 220 pF, 500 V	SAN	D155F221JO	C00550	2
C12, 16	Capacitor, dipped mica, 390 pF, 500 V	SAN	D155F391JO	C00640	2
C13	Capacitor, dipped mica, 470 pF, 500 V	SAN	D155F471JO	C00650	1
C14	Capacitor, dipped mica, 1500 pF, 500 V	SAN	D195E152JO	C00800	1
C18	Capacitor, dipped mica, 680 pF, 500 V	SAN	D155F681JO	C00680	1
C20, 33	Capacitor, dipped mica, 560 pF, 500 V	SAN	D155F561JO	C00670	2
C21	Capacitor, dipped mica, 27 pF, 500 V	SAN	D155F270JO	C00300	1
C22	Capacitor, dipped mica, 82 pF, 500 V	SAN	D155F820JO	C00440	1
C23	Capacitor, dipped mica, 1000 pF, 100 V	SAN	D151F102JO	C00710	1
C24	Capacitor, dipped mica, 18 pF, 500 V	SAN	D155F180JO	C00210	1
C28, 29	Capacitor, tubular trimmed, 0.8 - 8.5 pF	JFD	VC9CW	C02080	2
C36	Capacitor, dipped mica, 5 pF, 500 V	SAN	D155F050JO	C00130	1
CR1, 3	Diode	ITT	2N4152	D06420	2
CR2	Not used				
J1, 2	Connector, min. coax	SEA	50-051-0000	C03240	2
L1	Inductor, ferrite core, 4.7 μH	DEL	1537-64	I03640	1

Multiplier-Divider (32-5211) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
L2	Inductor, adjustable 1.8 - 3.0 μH	CAM	3370-10	I 11150	1
L3	Inductor, adjustable .27 - .40 μH	CAM	3370-5	I 11100	1
L4, 5	Inductor, air core	EE	10-4713		2
MC1	Integrated circuit, ECL dual 4-input gate	MOT	MC1023P		1
MC2	Integrated circuit, ECL J-K Flip-flop	MOT	MC1027P		1
MC3, 4	Integrated circuit, ECL J-K Flip-flop	MOT	MC1013P		2
Q1, 11	Transistor	FAI	2N3646	T04135	2
Q2-10	Transistor	FAI	2N3640	T04090	9
R1	Resistor, carbon 1.2k, 1/4W, 5%	AB		R01675	1
R2	Resistor, carbon 5.6k, 1/4W, 5%	AB		R01735	1
R3, 4	Resistor, carbon 2.7k, 1/4W, 5%	AB		R01705	2
R5, 38	Not used				
R6, 13, 14, 18, 22, 26, 30, 31, 33, 38, 49	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	11
R7, 43	Resistor, carbon 1.5k, 1W, 5%	AB		R02980	2
R8, 40, 41, 42	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	4
R9	Resistor, carbon 330Ω, 1/4W, 5%	AB		R01630	1
R10	Resistor, carbon 150Ω, 1/4W, 5%	AB		R01595	1
R11	Resistor, carbon 22Ω, 1/4W, 5%	AB		R01535	1
R12	Resistor, carbon 180Ω, 1/4W, 5%	AB		R01600	1
R15, 19, 23	Resistor, carbon 22k, 1/4W, 5%	AB		R01775	3
R16, 20, 24	Resistor, carbon 10k, 1/4W, 5%	AB		R01755	3
R17	Resistor, carbon 39k, 1/4W, 5%	AB		R01790	1

Multiplier-Divider (32-5211) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R21	Resistor, carbon 8.2k, 1/4W, 5%	AB		R01750	1
R23, 29	Resistor, carbon 1.8k, 1/2W, 5%	AB		R02300	2
R27	Resistor, carbon 15k, 1/4W, 5%	AB		R01765	1
R28	Resistor, carbon 6.8k, 1/4W, 5%	AB		R01740	1
R32	Resistor, carbon 390Ω, 1/4W, 5%	AB		R01635	1
R34	Resistor, carbon 15Ω, 1/4W, 5%	AB		R01525	1
R35, 36, 39	Resistor, carbon 2.2k, 1/4W, 5%	AB		R01695	3
R37, 45	Resistor, carbon 51Ω, 1/4W, 5%	AB		R01560	2
R44, 46	Resistor, carbon 220Ω, 1/4W, 5%	AB		R01610	2
R47, 48	Resistor, carbon 3.3k, 1/4W, 5%	AB		R01715	2
R50	Resistor, carbon 560Ω, 1/4W, 5%	AB		R01650	1

Start Up Oscillator (33-3453) Parts List

* Starred components are within oven

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1	Capacitor, dipped mica, 1000 pF, 100 V	SAN	D151F102JO	C00710	1
C2*	Capacitor, tubular trimmer, 1 - 14 pF	VOLT	TP14C	C00190	1
C3	Not used				
C4*	Capacitor, dipped mica, 10 pF, 500 V (typical value)	SAN	D155F100JO	C00180	1
C5*	Capacitor, disc ceramic, 22 pF	AERO	HLQN1500-22	C00260	1
C6*	Capacitor, dipped mica, 5 pF, 500 V	SAN	D155F050JO	C00130	1
C7*, 8*	Capacitor, precision mica, 270 pF	JFD	UY03271-G	C00580	2
C9*, 11*, 12, 13, 14, 15	Capacitor, Mylar 0.1 μF, 250 V	AMPE	C280AE/P100K	C01301	6
C10*	Capacitor, dipped mica, 15 pF, 500 V	SAN	D155F150JO	C00200	1
CR1, 5*, 6*	Diode	GE	1N4154	D06440	3
CR2*	Diode	FAI	FD700	D00700	1
CR3*	Diode, varicap		MV1620		1
CR4*, 7*	Diode, zener	TI	1N749A	D02030	2
CR8	Diode, zener	TI	1N757A	D02110	1
FB1*, 2*, 3, 4	Ferrite Bead	FER	56-590-6503B		4
J1, 2, 3, 4	Connector, min. coax	SEA	51-051-0000	C03240	4
L1*	Inductor, etched, 1.5 μH	JFD	LF2W150		1
Q1, 3*, 5, 6	Transistor	FAI	2N209	T03290	4
Q2, 4*, 7, 8	Transistor	FAI	2N3640	T04090	4
R1	Resistor, carbon 1.5k, 1/4W, 5%	AB		R01680	1
R2, 11*, 21, 22, 25	Resistor, carbon 47Ω, 1/4W, 5%	AB		R01555	5
R3, 10*	Resistor, carbon 10k, 1/4W, 5%	AB		R01755	2
R4	Resistor, carbon 1k, 1/4W, 5%	AB		R01670	1
R5	Resistor, carbon 180Ω, 1/4W, 5%	AB		R01600	1

Start Up Oscillator (33-3453) Parts List continued

* Starred components are within oven

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
R6	Potentiometer, miniature 500Ω	CTS	385PC501A	P02150	1
R7*, 13*	Resistor, metal film 470Ω, 1/4W, 2%	IRC	RL07AD471GO	R10560	2
R8*, 9*	Resistor, metal film 2.2k, 1/4W, 2%	IRC	RL07AD222GO	R10580	2
R12*, 26	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	2
R14*, 15*	Resistor, metal film 220Ω, 1/4W, 2%	IRC	RL07AD221GO	R10480	2
R16	Resistor, carbon 680Ω, 2W, 5%	AB		R03420	1
R17	Resistor, carbon 22Ω, 1/4W, 5%	AB		R01535	1
R18, 20	Resistor, carbon 560Ω, 1/4W, 5%	AB		R01650	2
R19	Resistor, carbon 680Ω, 1/4W, 5%	AB		R01660	1
R23	Resistor, carbon 820Ω, 2W, 5%	AB		R03425	1
R24	Resistor, carbon 2.2k, 1/4W, 5%	AB		R01695	1
R27	Resistor, carbon 15k, 1/4W, 5%	AB		R01765	1
R28	Resistor, carbon 82k, 1/4W, 5%	AB		R01820	1

Reference Oscillator (C-33-04970) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1	Capacitor, tubular trimmer, 0.5 - 3.0 pF	JFD	VC256		1
C2	Capacitor, trimmer 8.50 pF	ERR	557-091-UZPO-34R		1
C3	Capacitor, dipped mica, 560 pF, 500 V	SAN	D155F561JO	C00670	1
C4	Capacitor, dipped mica, 470 pF, 500 V	SAN	D155F471JO	C00650	1
C5, 6	Capacitor, Mylar 0.1 μF, 250 V	AMPE	C280AE/P100K	C01304	2
C7	Capacitor, Mylar .002 μF	ERR	835/Z5U/202P	C00832	1
Q1, 2	Transistor	TI	2N3707		2
R1	Resistor, carbon 47k, 1/4W, 5%	AB		R01795	1
R2, 5, 6	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	3
R3, 4	Resistor, carbon 2.7k, 1/4W, 5%	AB		R01705	2
Y1	Crystal, 1 MHz	Filtaire	Blue Dot	C03410	1
YS1	Crystal socket	AUG	8000-DG1	S01955	1

Power Supply and Regulator (D-4-04917) Parts List

Components preceded by + (e.g., +C17) on PC board A-32-3042-G, the + Regulator, components with a - (-Q13), are on A-32-04507, the - Regulator. Unmarker components (Q4), are on the Power Supply assembly, C-45-05041.

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1, 10	Capacitor, electrolytic 900 μF, 75 V	SAN	593-2554-01	C01930	2
C2, 11	Capacitor, electrolytic 4000 μF, 35 V	SAN	593-2641-01	C01980	2
-C3, -6, +15	Capacitor, electrolytic 200 μF, 15 V	SPR	TE1164	C01840	3
-C4, +13	Capacitor, electrolytic 50 μF, 50 V	SPR	TE1307	C01800	2
-C5, +14, +19	Capacitor, paper 0.1 μF, 250 V	SIE	B32232-A3104K	C01300	3
-C7, +18	Capacitor, electrolytic 10 μF, 50 V	SPR	TE1304	C01620	2
-C8, -4, +16, +17	Capacitor, electrolytic 50 μF, 15 V	SPR	TE1160	C01780	4
C12	Capacitor, electrolytic 8 μF, 450 V	SPR	TVA-1704	C01580	1
-CR1	Diode	SEM	SC-10	D01150	1
CR2	Not used				
-CR3, +13, +14, +16	Diode, signal	EE	3-1001	D09000	4
-CR4, +15	Diode, zener	TI	1N753A	D02070	2
+CR5, 6, 7, 8, 10, 12	Diode, Rectifier	SEM	SC-2	D01200	6
-CR9, -11	Diode, Rectifier	SOL	2A-100	D06540	2
Line Filter		EE	10-3451	300540	1
Q1	Transistor, power	MOT	2N1546	T03620	1
Q2, 3, 5, 6	Transistor, power	MOT	2N1544	T03600	4
Q4	Transistor, power	RCA	2N3054	T04020	1
-Q7, -13, -15	Transistor	EE	4-1002	T08010	4
-Q8, 9	Transistor	TI	2N3703	T04170	2
+Q10, 12, 16	Transistor	RCA	2N3053	T04010	3
+Q11, 17, 18	Transistor	GE	2N2712	T03890	3
-R1, +19	Resistor, wirewound 7.5Ω, 3W	SPR	242E7R55	R10020	2
-R2, 7, +24	Resistor, carbon 1.2k, 1/4W, 5%	AB		R01675	3

Power Supply and Regulator (D-4-04917) Parts List continued

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
-R3, +21	Resistor, carbon 2.7k, 1/4W, 5%	AB		R01705	2
-R4, +22	Resistor, carbon 100Ω, 1/4W, 5%	AB		R01585	2
-R5	Resistor, carbon 8.2k, 1/4W, 5%	AB		R01750	1
-R6, +28	Resistor, carbon 820Ω, 1/4W, 5%	AB		R01665	2
-R8, +25, 26, 39	Potentiometer, PC mount 200Ω, 1/2W, 10%	CTS	BJ89103		4
-R9, +23	Resistor, carbon 2.2k, 1/4W, 5%	AB		R01695	2
-R10, 17, +27	Resistor, carbon 470Ω, 1/4W, 5%	AB		R01640	4
-R11, -18	Resistor, carbon 1.5k, 1/4W, 5%	AB		R01680	2
-R12	Resistor, carbon 680Ω, 1/4W, 5%	AB		R01660	1
-R13	Resistor, carbon 330Ω, 1/4W, 5%	AB		R01630	1
-R14, +37	Potentiometer, PC mount 100Ω, 1/2W, 10%	CTS	BJ89102		2
-R15	Resistor, carbon 10k, 1/4W, 5%	AB		R01755	1
-R16, +34	Resistor, carbon 560Ω, 1/4W, 5%	AB		R01650	2
+R20	Resistor, carbon 1.8k, 1W, 5%	AB		R02985	1
+R29	Resistor, carbon 1.8k, 1/4W, 5%	AB		R01685	1
+R30	Resistor, carbon 3.9k, 1/4W, 5%	AB		R01720	1
+R31, 32	Resistor, carbon 220Ω, 1/4W, 5%	AB		R01605	2
+R33, 35	Resistor, carbon 3.3k, 1/4W, 5%	AB		R01715	2
+R36	Resistor, carbon 560Ω, 1/4W, 5%	AB		R01650	1
-R40	Resistor, carbon 560k, 1/2W, 5%	AB		R02500	1
T1	Transformer, power	EE	11-2772	T02540	1

Logic Chassis (C-45-04878) Parts List

Components in parenthesis are options

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
A1, 4, 5, 24-30, 32, 34, 36, 38, 40, 42, 45	Not used				
A2	Discriminator, PCB ass'y	EE	10-4814		1
A3	Logic Circuit, PCB ass'y	EE	10-4804		1
A6, 8, 10, 12, 14, 16, (18, 20, 22)	Memory Readout, PCB ass'y	EE	10-4962		6 (9)
A7, 11	25 MHz DCU, PCB ass'y	EE	10-3968		2
A9, 13	2.5 MHz DCU, PCB ass'y	EE	10-3967		2
A15, 17, (19, 21, 23)	250 kHz DCU, PCB ass'y	EE	10-3966		2 (5)
(A31)	Oven Regulator, PCB ass'y	EE			(1)
A33	Test Pulser, PCB ass'y	EE	10-4942		1
A35	Coincidence Gate, PCB ass'y	EE	10-4803		1
A37	Stop Circuit, PCB ass'y	EE	10-04903		1
A39	Add-one, PCB ass'y	EE	10-04948		1
A41	Stabilizer, PCB ass'y	EE	10-05011		1
A46	Multiplier, PCB ass'y	EE	10-04547		1
C1-9	Capacitor, Mylar 0.1 μF, 250 V	AMPE	C280AE/P100K	C01304	9
J1, 4, 5, 24, 27-30, 32, 34, 36, 38, 40, 42-45	Not used				
J3, 4	Connector, special PC	EE	10-4379	201245	2
J6, 8, 10, 12, 14, 16, (18, 20, 22)	Connector, special PC	EE	10-4380	201245	6 (9)
J7, 9, 11, 13, 15, 17, (19, 21, 23, 31), 35, 37, 39, 41, 46	Connector, PC	ELC	00-6024-18-940-004	C02780	12 (16)
J25, 26	Connector, special PC	EE	10-4378	201240	2
R1, 2	Resistor, carbon 390Ω, 1/2W, 5%	AB		R02245	2

Oscillator Chassis (C-45-04715) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
C1	Capacitor, disc ceramic, .01 μF, 100 V	SPR	TGS-10	C01000	1
C2	Capacitor, Mylar 0.1 μF, 400 V	AMPE	C280AF/P100K	C01332	1
CR1	Diode, zener	TI	1N752A	D02060	1
J1, 2, 3	Socket, octal		8AM	S01900	3
R1	Potentiometer, 10k	CLAR	53C3-10K		1
R2	Potentiometer, 1k	CLAR	53C3-1K-S		1
R3	Resistor, carbon 2.2k, 1W, 5%	AB		R02990	1
R4	Resistor, carbon 470Ω, 1/2W, 5%	AB		R02250	1
R5	Resistor, carbon 220Ω, 1/2W	AB		R02225	1
S1	Switch, slide, DPDT	SMH	518	S05700	1
T1	Transformer	TRX	4-1681		1

Attenuator (C-40-04884) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
Cable	RG-188/U Coax	AML			A/R 22"
P1	Coax Connector, female BNC	AML	025-83600-75	C02820	1
P2	Coax Connector, min. 90° male	SEA	51-28-0000	C03120	1
R1, 3	Resistor, metal film 150Ω, 1/4W, 1%	TI	MC55D1500F		2
R2	Resistor, metal film 37.4Ω, 1/4W, 1%	TI	MC55D37R4F		1
R4, 6	Resistor, metal film 82.5Ω, 1/4W, 1%	TI	MC55D82R5F		2
R5	Resistor, metal film 93.1Ω, 1/4W, 1%	TI	MC55D93R1F		1
R7, 9	Resistor, metal film 64.9Ω, 1/4W, 1%	TI	MC55D64R9F		2
R8	Resistor, metal film 196Ω, 1/4W, 1%	TI	MC55D1960F		1
R10, 12	Resistor, metal film 56.2Ω, 1/4W, 1%	TI	MC55D56R2F		2
R11	Resistor, metal film 392Ω, 1/4W, 1%	TI	MC55D3920F		1
R13, 15	Resistor, metal film 53.6Ω, 1/4W, 5%	TI	MC55D53R6F		2
R14	Resistor, metal film 787Ω, 1/4W, 5%	TI	MC55D7870F		1
R16, 18, 19, 21	Resistor, metal film 51.1Ω, 1/4W, 5%	TI	MC55D51R1F		4
R17	Resistor, metal film 1620Ω, 1/4W, 1%	TI	MC55D1621F		1
R20	Resistor, metal film 3240Ω, 1/4W, 1%	TI	MC55D3241F		1
S1	Switch, special shielded 2 pole, 8 position	EE	10-04636		1

Front Panel Assembly (45-04862) Parts List

Component	Description	Mfgr.	Mfgr. No.	EE No.	Qty.
RESET button	SPST NO pushbutton	HET	B-2001	S05050	1
NULL pot	5k screwdriver pot	CTS	RV4NAYSD502A		1
DISPLAY MODE switch	Switch ass'y	CTS	51969	S05725	1
A Multiplier B Multiplier	Attenuator ass'y	EE	10-4884		2
A Trigger Level B Trigger Level	50Ω potentiometer	CTS	RV4NRY5D500A		2
A, B, polarity slope switches	Miniature DPDT, toggle switch	OK	7201		4
DISPLAY TIME potentiometer	1 Meg potentiometer, DPST switch	CTS	204646		1
Mode switch	3-position rotary switch	EE	10-04635		1

Model 796 Final Assembly Parts List

Components in parenthesis are options

Component	Mfgr.	Mfgr. No.	EE No.	Qty.
Front panel ass'y	EE	10-4862		1
Logic chassis w/PC cards	EE			1
Oscillator chassis w/oscillator	EE			1
Power Supply ass'y	EE	10-05401		1
Rear panel ass'y	EE	10-4866		1
Nixie tube	BUR	B05092		6 (9)
Handle	PHIL	774-280-324SS3/4	H00150	2
Fan	HOW	8011	F00100	1
Display filter	EE	10-07191		1
Delay box ass'y	EE	10-04944		1
Knob	RAY	670-3-26		7
Bail	BUCK		I 12002	1
Cable ass'y, 18"	EE	10-05386		1
16"	EE	10-04941		1
12"	EE	10-04940		1
9"	EE	10-04939		2
8"	EE	10-04938		2
7"	EE	10-04937		2
6"	EE	10-04936		2
Fuse, 4A MDL				1
Fuse, 3A AGC				2
Fuse, 1A AGC				1
Fuse, 0.5A AGC				1

CHAPTER 7

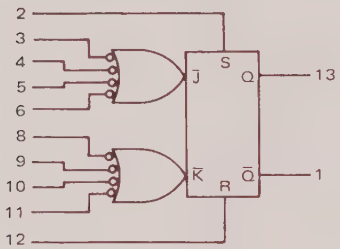
SCHEMATICS AND DRAWINGS

Integrated Circuit Schematic Equivalent

MC1027

Designed for use at clock frequencies to 100 MHz minimum (120 MHz typical). Logic performing inputs ($\bar{J}$ and $\bar{K}$) are available, as well as dc SET and RESET inputs.

POSITIVE LOGIC



DC Input Loading Factor = 2
DC Output Loading Factor = 25
Power Dissipation = 250 mW typical

R-S TRUTH TABLE

Pin No.

R	S	Q^{n+1}
12	2	13
0	0	Q^n
0	1	1
1	0	0
1	1	N.D.

All $\bar{J}$-$\bar{K}$ Inputs Are Static

$\bar{J}_D$-$\bar{K}_D$ TRUTH TABLE

Pin No.

$\bar{J}_D$	$\bar{K}_D$	Q^{n+1}
*	*	13
0	0	Q^n
0	1	0
1	0	1
1	1	$\bar{Q}^n$

All Other $\bar{J}$-$\bar{K}$ Inputs And The R-S Inputs Are At a "0" Level

CLOCKED $\bar{J}$-$\bar{K}$ TRUTH TABLE

Pin No.

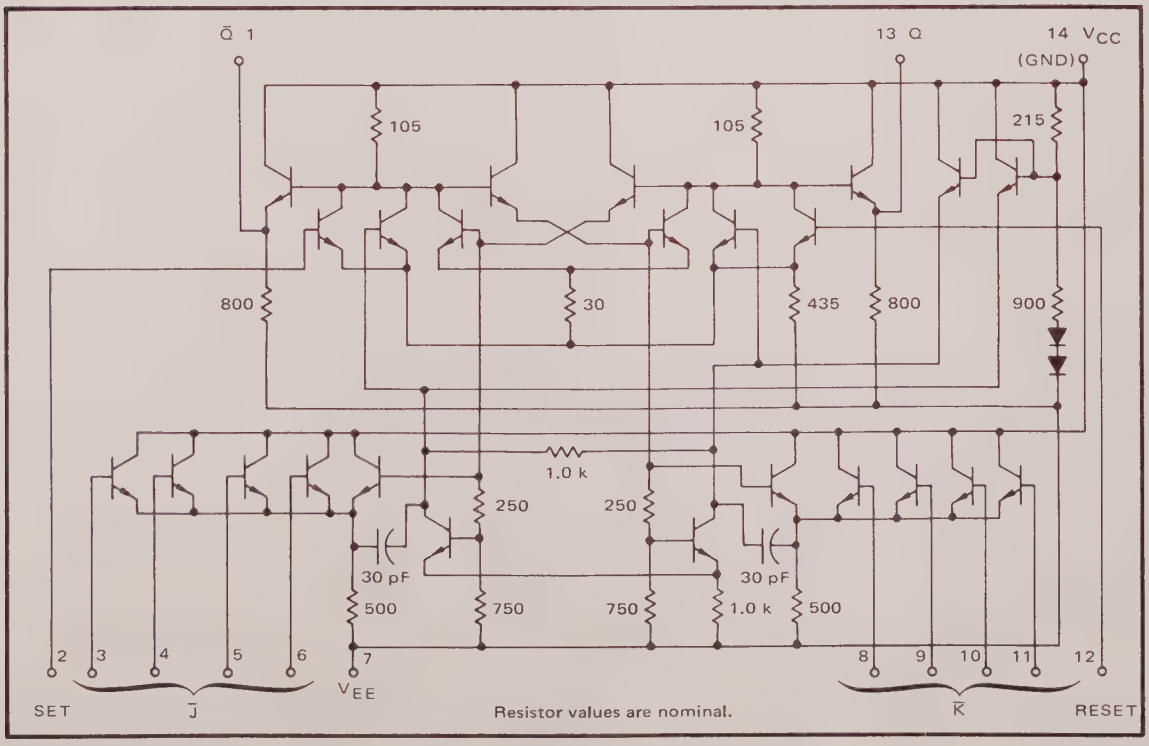
$\bar{J}$	$\bar{K}$	$\bar{C}_D$	Q^n
*	*	**	13
ϕ	ϕ	0	Q^n
0	0	1	$\bar{Q}^n$
0	1	1	1
1	0	1	0
1	1	1	Q^n

All Other $\bar{J}$-$\bar{K}$ Inputs And The R-S Inputs Are At a "0" Level

*Any $\bar{J}$ or $\bar{K}$ input, not used for $\bar{C}_D$.
**$\bar{C}_D$ obtained by connecting one $\bar{J}$ and one $\bar{K}$ input together.

The $\bar{J}$ and $\bar{K}$ inputs refer to logic levels while the $\bar{C}_D$ input refers to dynamic logic swings. The $\bar{J}$ and $\bar{K}$ inputs should be changed to a logical "1" only while the $\bar{C}_D$ input is in a logic "1" state. ($\bar{C}_D$ maximum "1" level = V_{CC} −0.6 V). Clock $\bar{C}_D$ is obtained by tying one $\bar{J}$ and one $\bar{K}$ input together.

CIRCUIT SCHEMATIC

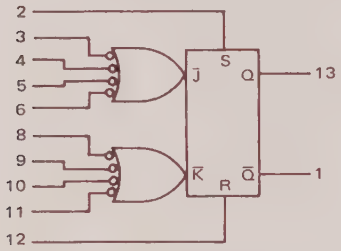


Integrated Circuit Schematic Equivalent

MC1013
MC1213

Designed for use at clock frequencies to 70 MHz minimum (85 MHz typical). Logic performing inputs ($\bar{J}$ and $\bar{K}$) are available, as well as dc SET and RESET inputs.

POSITIVE LOGIC



DC Input Loading Factor = 1
DC Output Loading Factor = 25
Power Dissipation = 125 mW typical

R-S TRUTH TABLE

Pin No.	R	S	Q^{n+1}
	12	2	13
	0	0	Q^n
	0	1	1
	1	0	0
	1	1	N.D.

All $\bar{J}$-$\bar{K}$ Inputs Are Static

$\bar{J}_D$-$\bar{K}_D$ TRUTH TABLE

Pin No.	$\bar{J}_D$	$\bar{K}_D$	Q^{n+1}
	*	*	13
	0	0	Q^n
	0	1	0
	1	0	1
	1	1	$\bar{Q}^n$

All Other $\bar{J}$-$\bar{K}$ Inputs And The R-S Inputs Are At a "0" Level

CLOCKED $\bar{J}$-$\bar{K}$ TRUTH TABLE

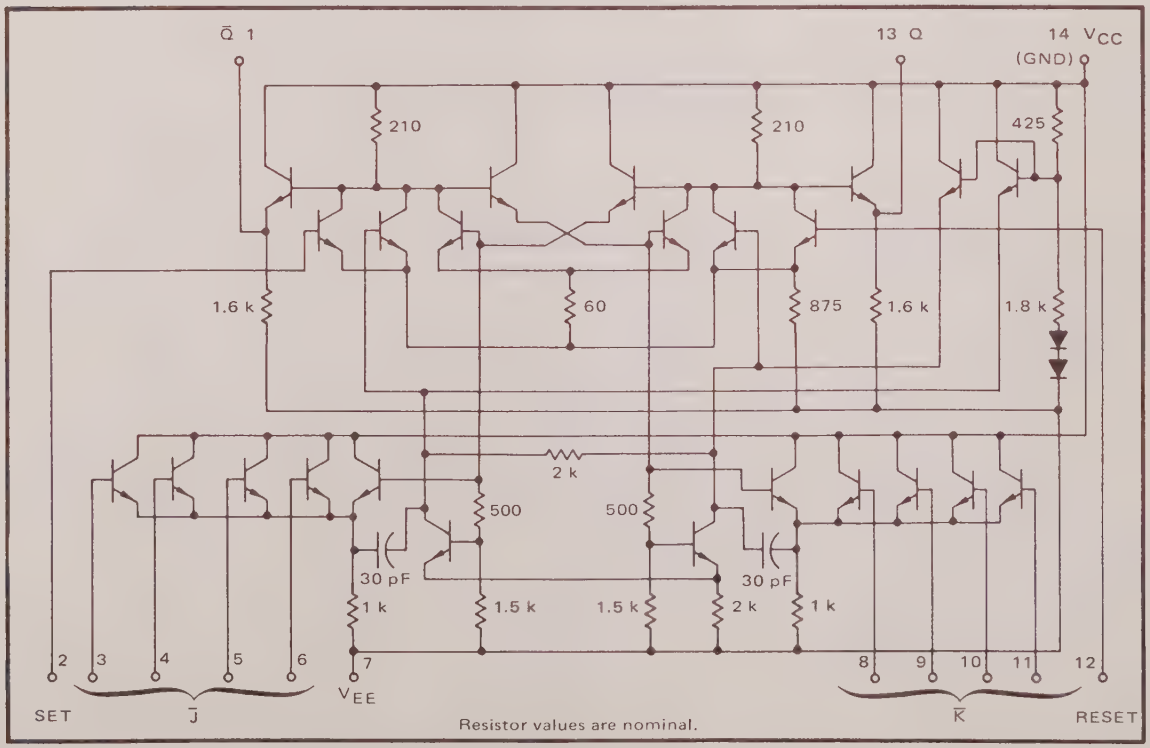
Pin No.	$\bar{J}$	$\bar{K}$	$\bar{C}_D$	Q^n
	*	*	**	13
	ϕ	ϕ	0	Q^n
	0	0	1	$\bar{Q}^n$
	0	1	1	1
	1	0	1	0
	1	1	1	Q^n

All Other $\bar{J}$-$\bar{K}$ Inputs And The R-S Inputs Are At a "0" Level

*Any $\bar{J}$ or $\bar{K}$ input, not used for $\bar{C}_D$.
**$\bar{C}_D$ obtained by connecting one $\bar{J}$ and one $\bar{K}$ input together.

The $\bar{J}$ and $\bar{K}$ inputs refer to logic levels while the $\bar{C}_D$ input refers to dynamic logic swings. The $\bar{J}$ and $\bar{K}$ inputs should be changed to a logical "1" only while the $\bar{C}_D$ input is in a logic "1" state. ($\bar{C}_D$ maximum "1" level = V_{CC} −0.6 V). Clock $\bar{C}_D$ is obtained by tying one $\bar{J}$ and one $\bar{K}$ input together.

CIRCUIT SCHEMATIC



Resistor values are nominal.

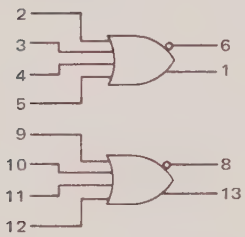
Integrated Circuit Schematic Equivalent

MC1023

Provides simultaneous OR-NOR or AND-NAND output functions. It contains an internal bias reference insuring that the threshold point is always in the center of the transition region over the temperature range.

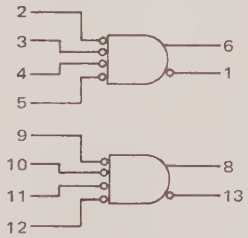
This circuit is designed to operate in high-speed digital computer applications as a clock driver or as a high-speed gate.

POSITIVE LOGIC



$6 = \overline{2 + 2 + 4 + 5}$
$1 = 2 + 3 + 4 + 5$

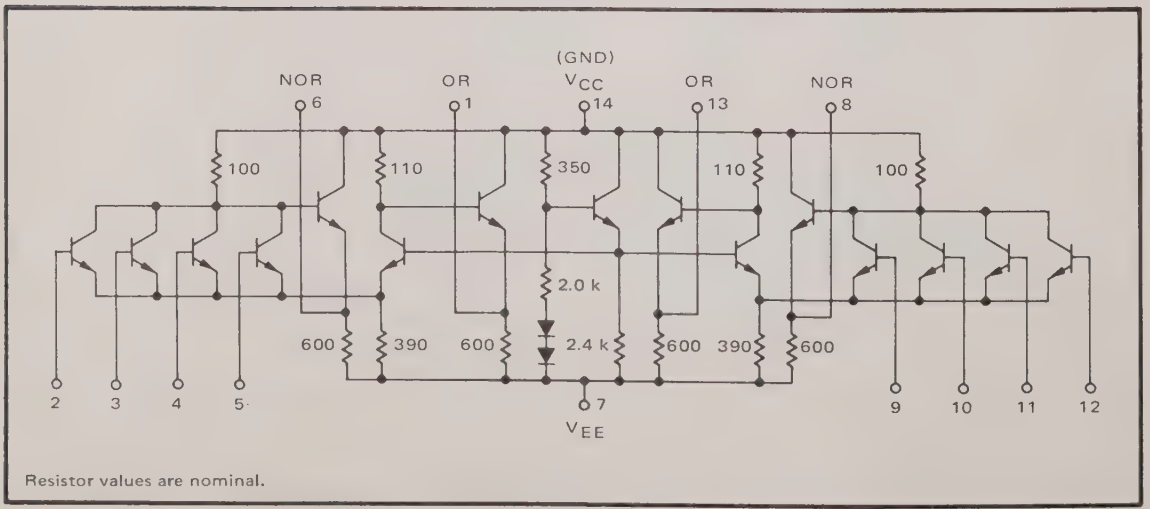
NEGATIVE LOGIC



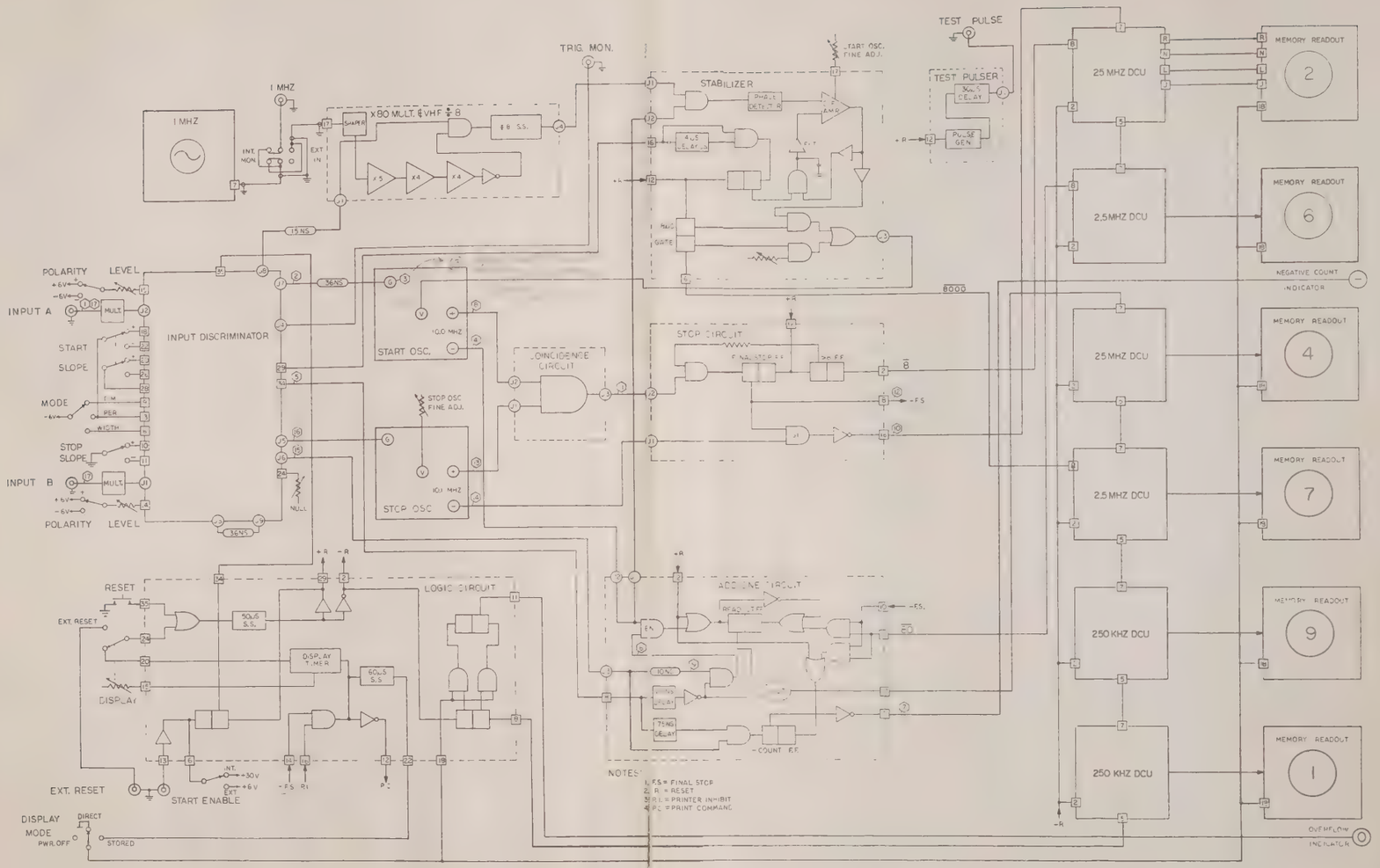
$6 = \overline{2 \bullet 3 \bullet 4 \bullet 5}$
$1 = 2 \bullet 3 \bullet 4 \bullet 5$

DC Input Loading Factor = 3
DC Output Loading Factor = 25
Power Dissipation = 250 mW typical

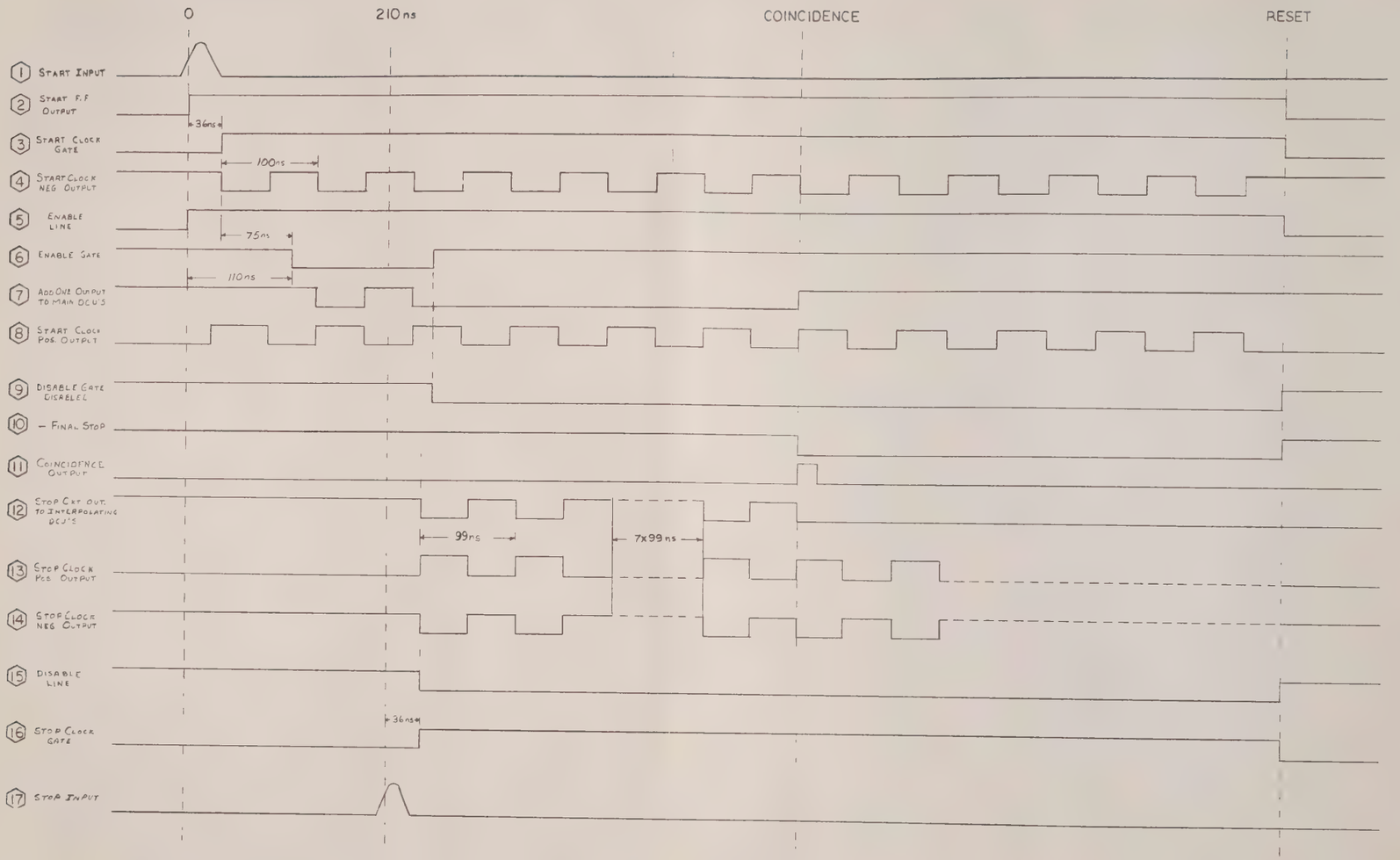
CIRCUIT SCHEMATIC



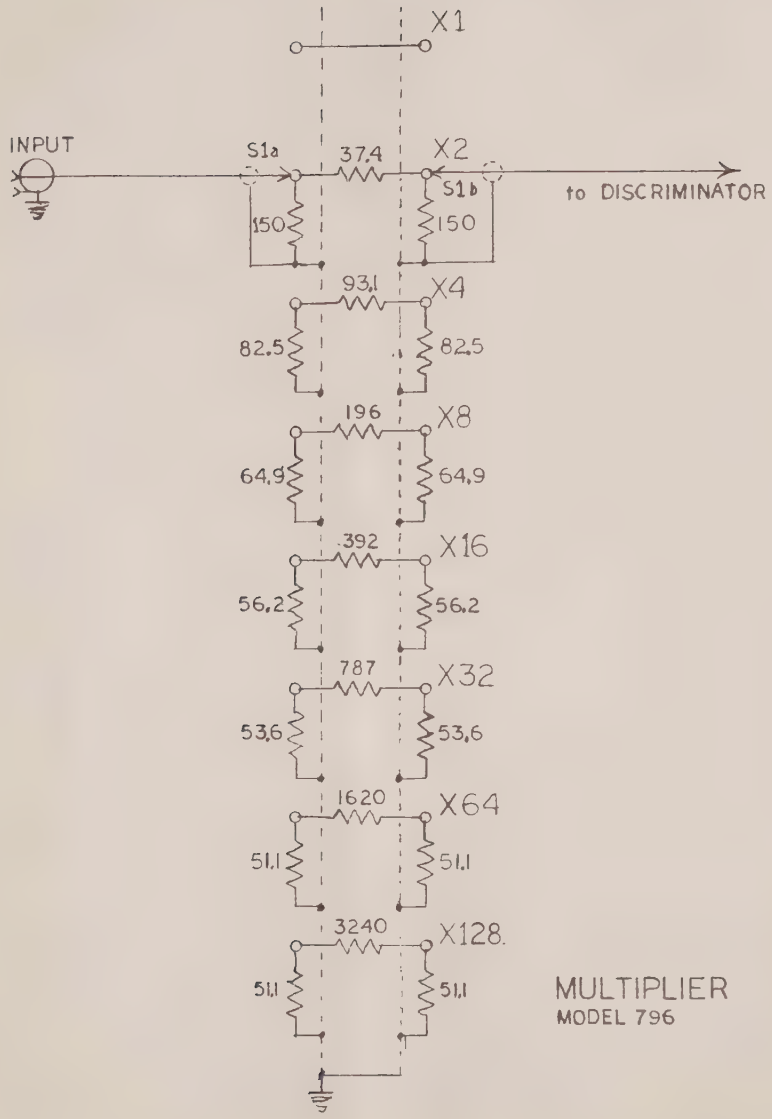
Resistor values are nominal.



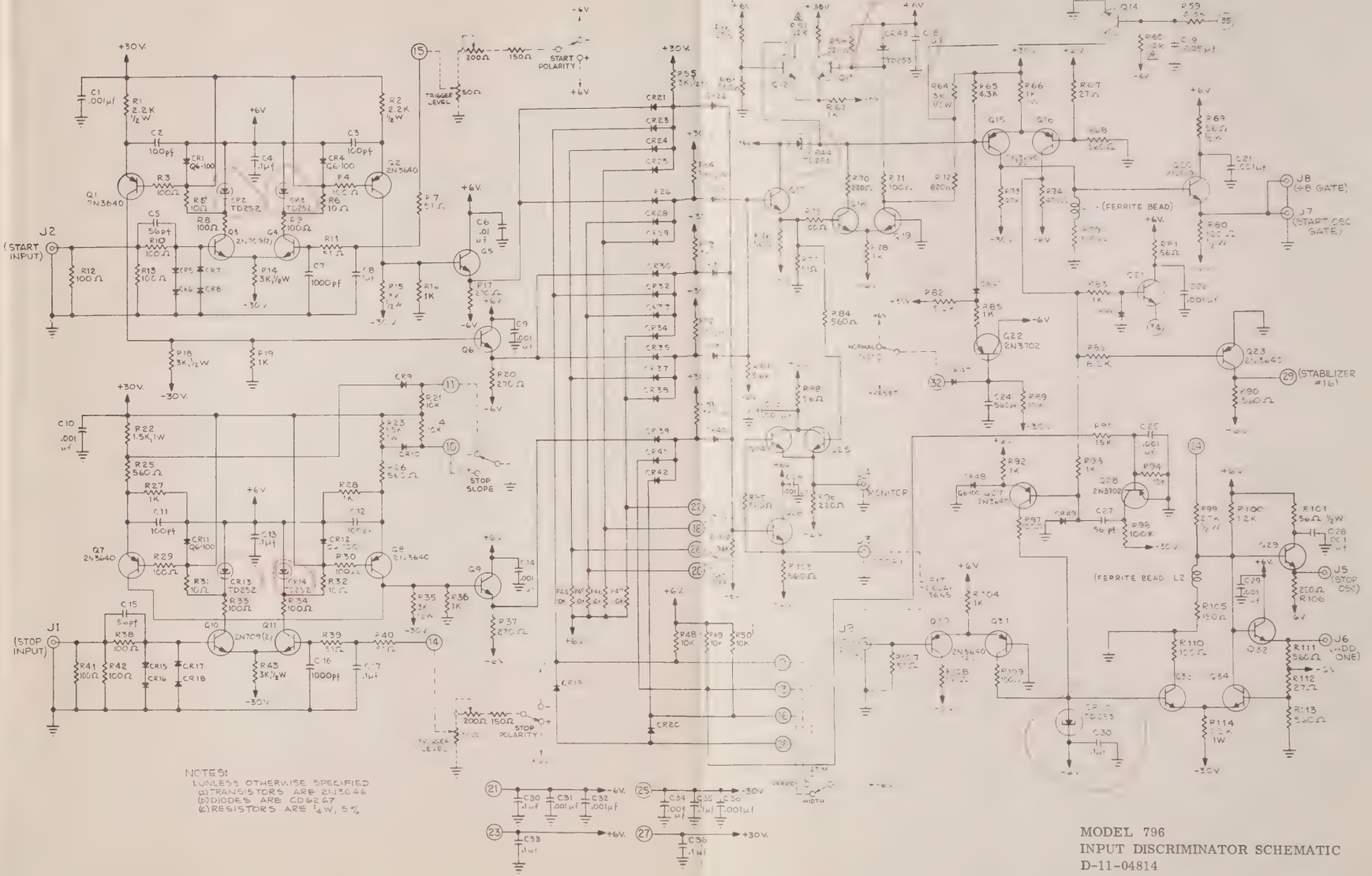
MODEL 796
BLOCK DIAGRAM
D-10-04935



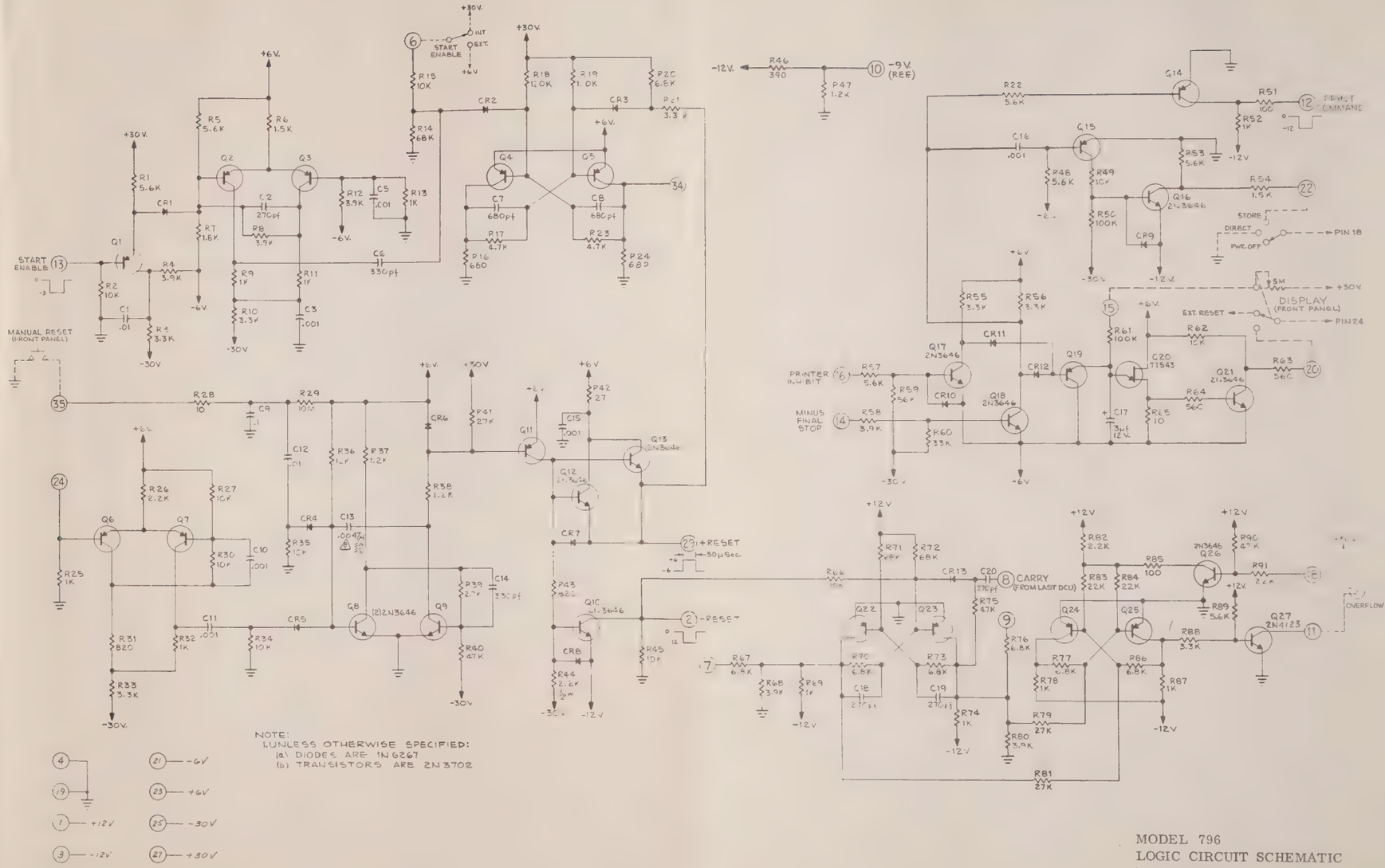
MODEL 796
TIMING DIAGRAM



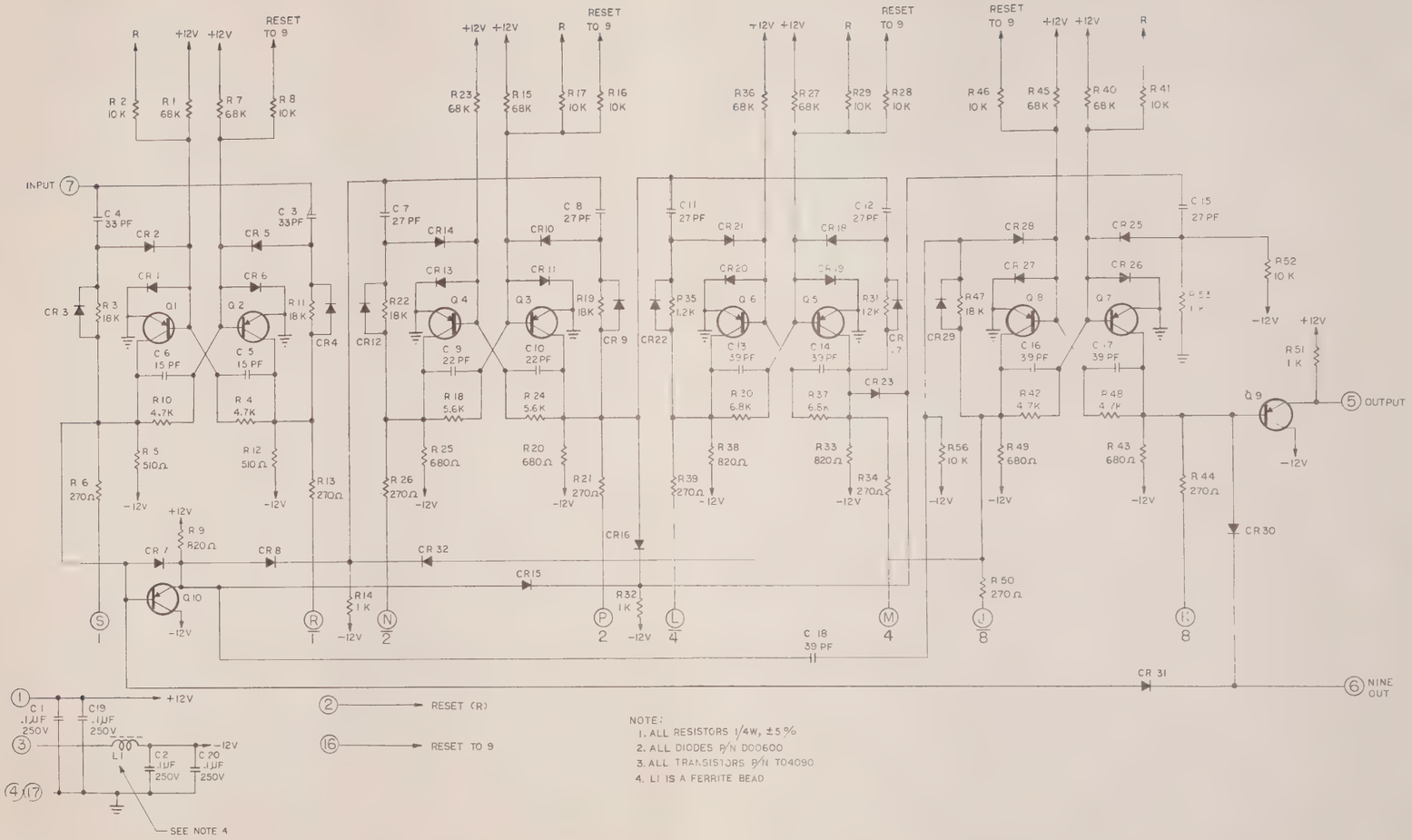
MULTIPLIER
MODEL 796



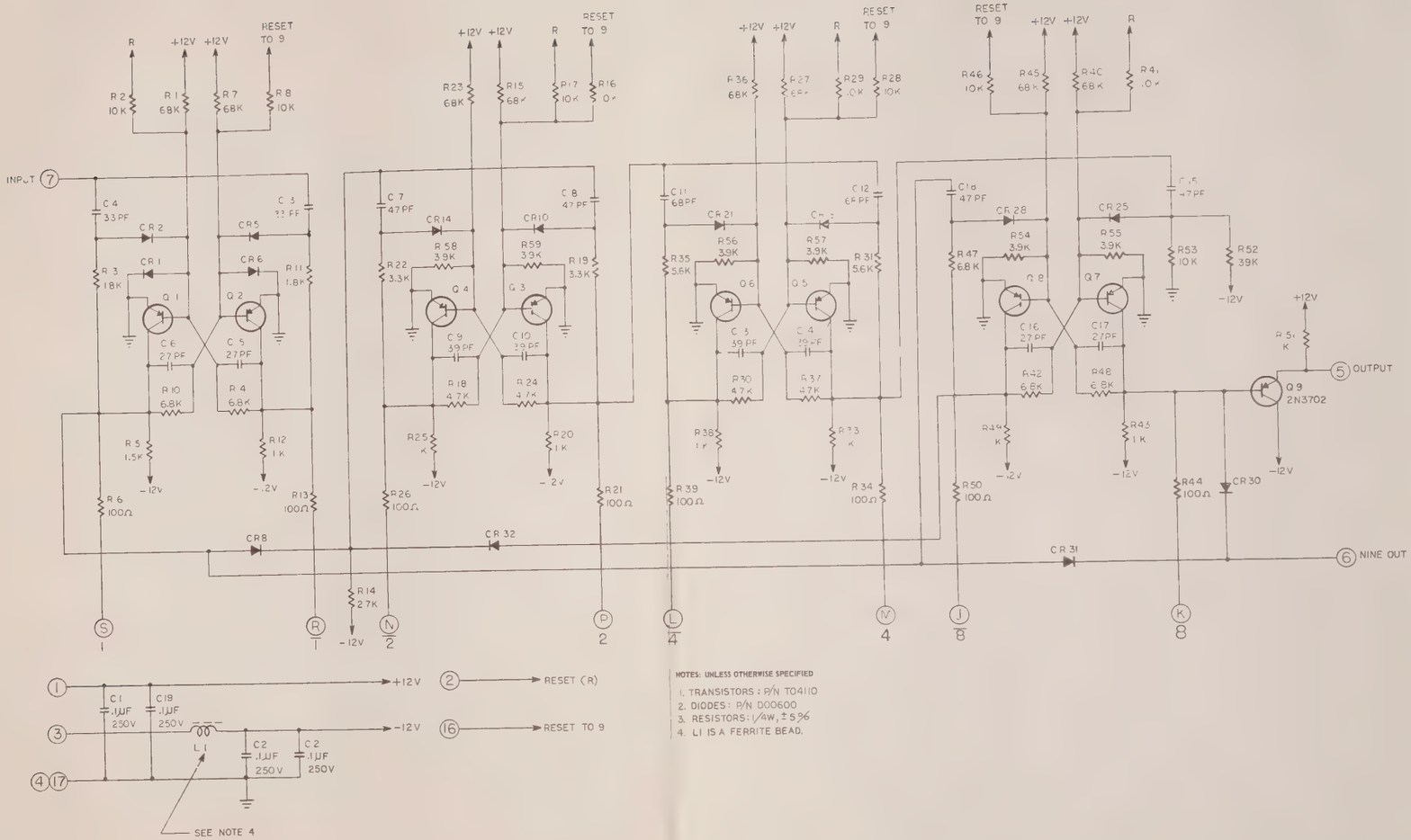
MODEL 796
INPUT DISCRIMINATOR SCHEMATIC
D-11-04814



MODEL 796
LOGIC CIRCUIT SCHEMATIC
D-11-04804



MODEL 796
25 MHz DCU SCHEMATIC
D-11-03968

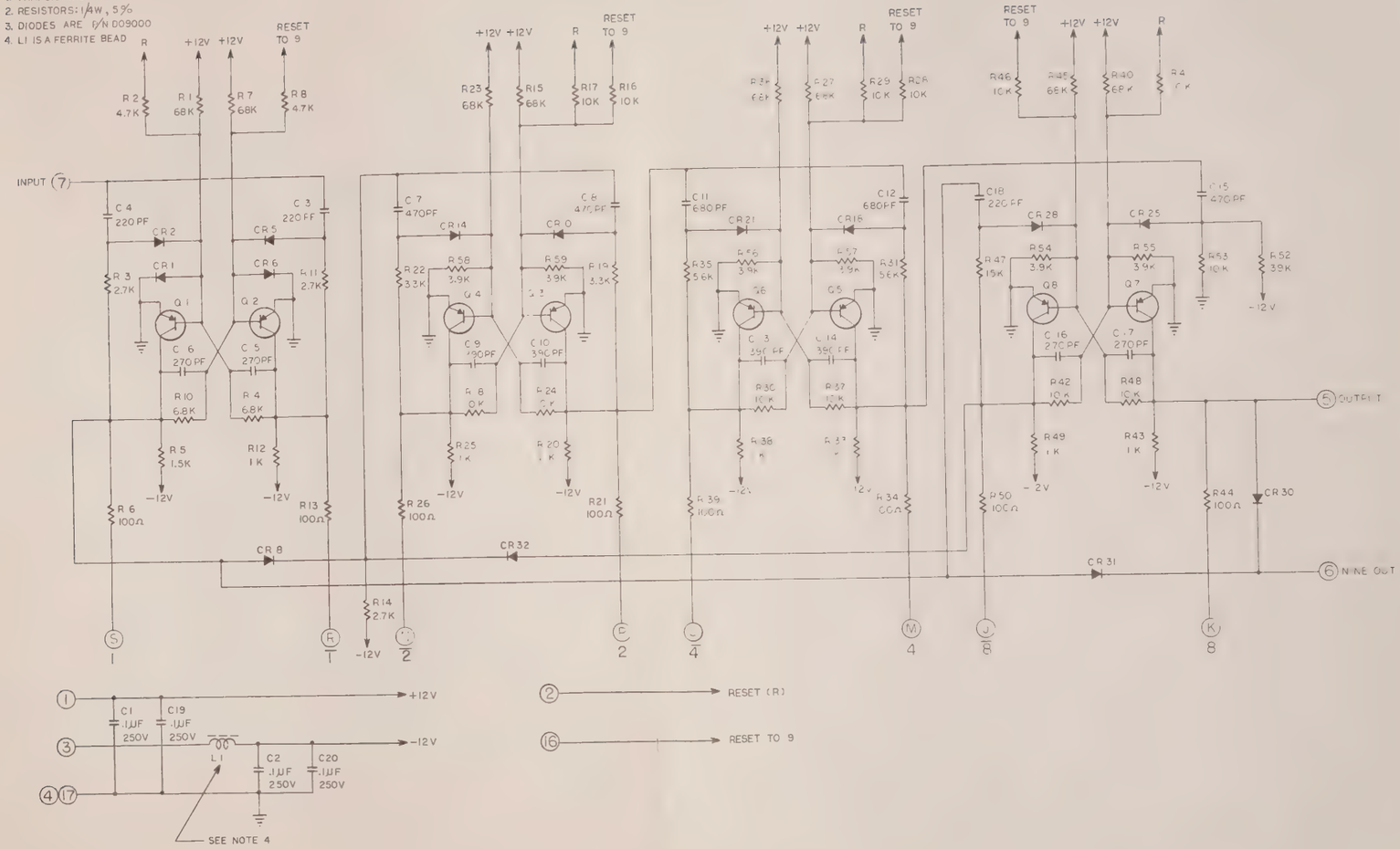


NOTES: UNLESS OTHERWISE SPECIFIED

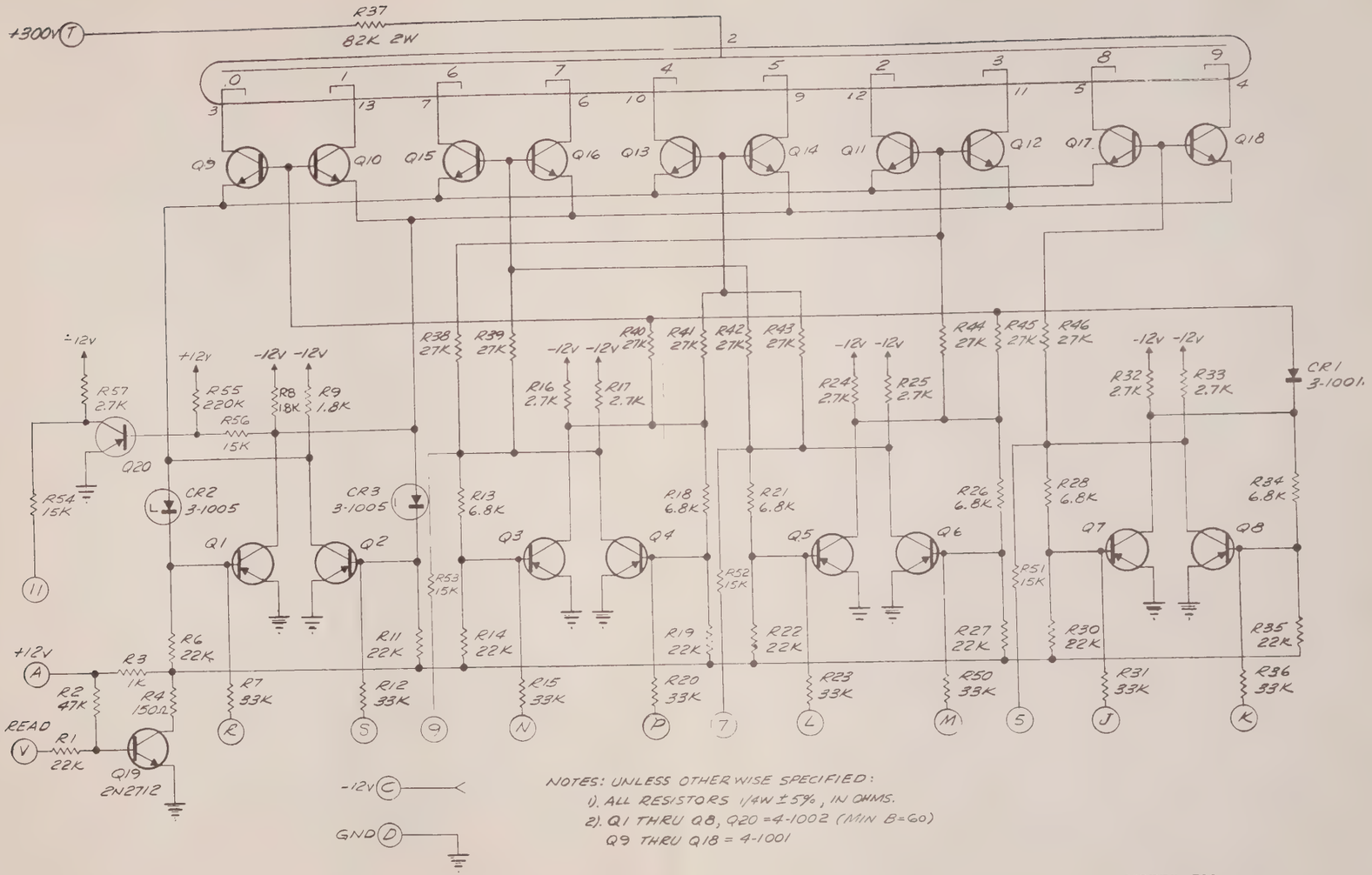
1. TRANSISTORS : P/N T04110
2. DIODES : P/N D00600
3. RESISTORS: 1/4W, ±5%
4. L1 IS A FERRITE BEAD.

MODEL 796
2.5 MHz DCU SCHEMATIC
D-11-3967

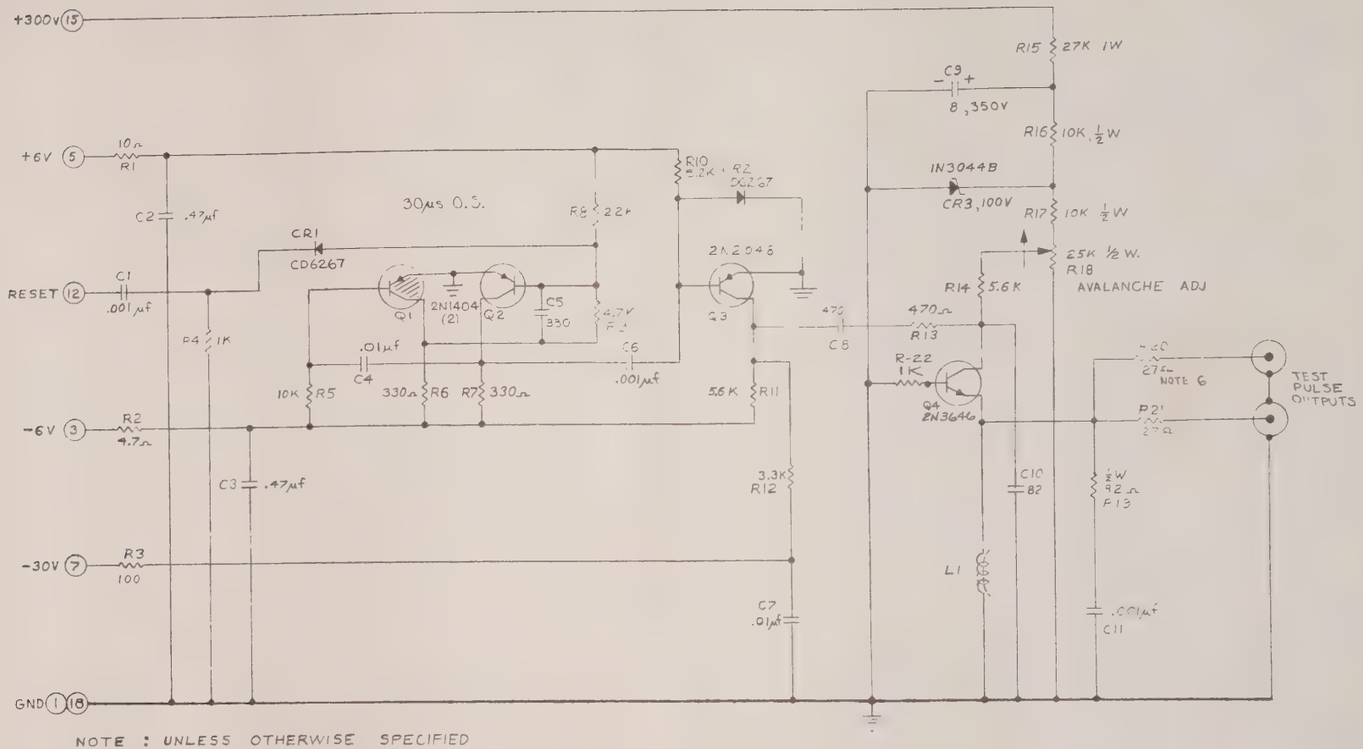
NOTES UNLESS OTHERWISE SPECIFIED
1. TRANSISTORS ARE P/N TO4160
2. RESISTORS: 1/4W, 5%
3. DIODES ARE P/N D09000
4. L1 IS A FERRITE BEAD



MODEL 796
250 kHz DCU SCHEMATIC
D-11-3966



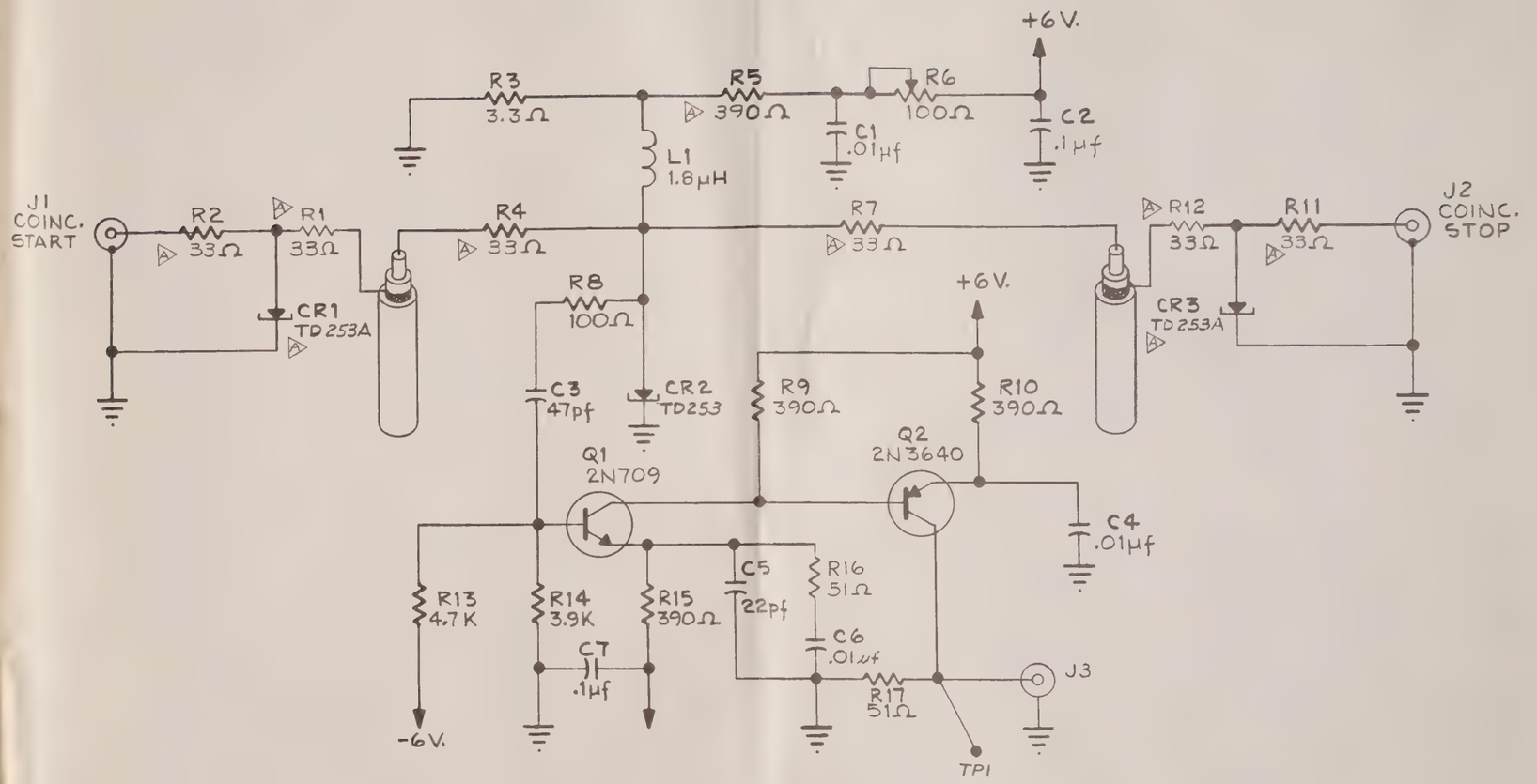
MODEL 796
MEMORY READOUT SCHEMATIC
D-11-04962



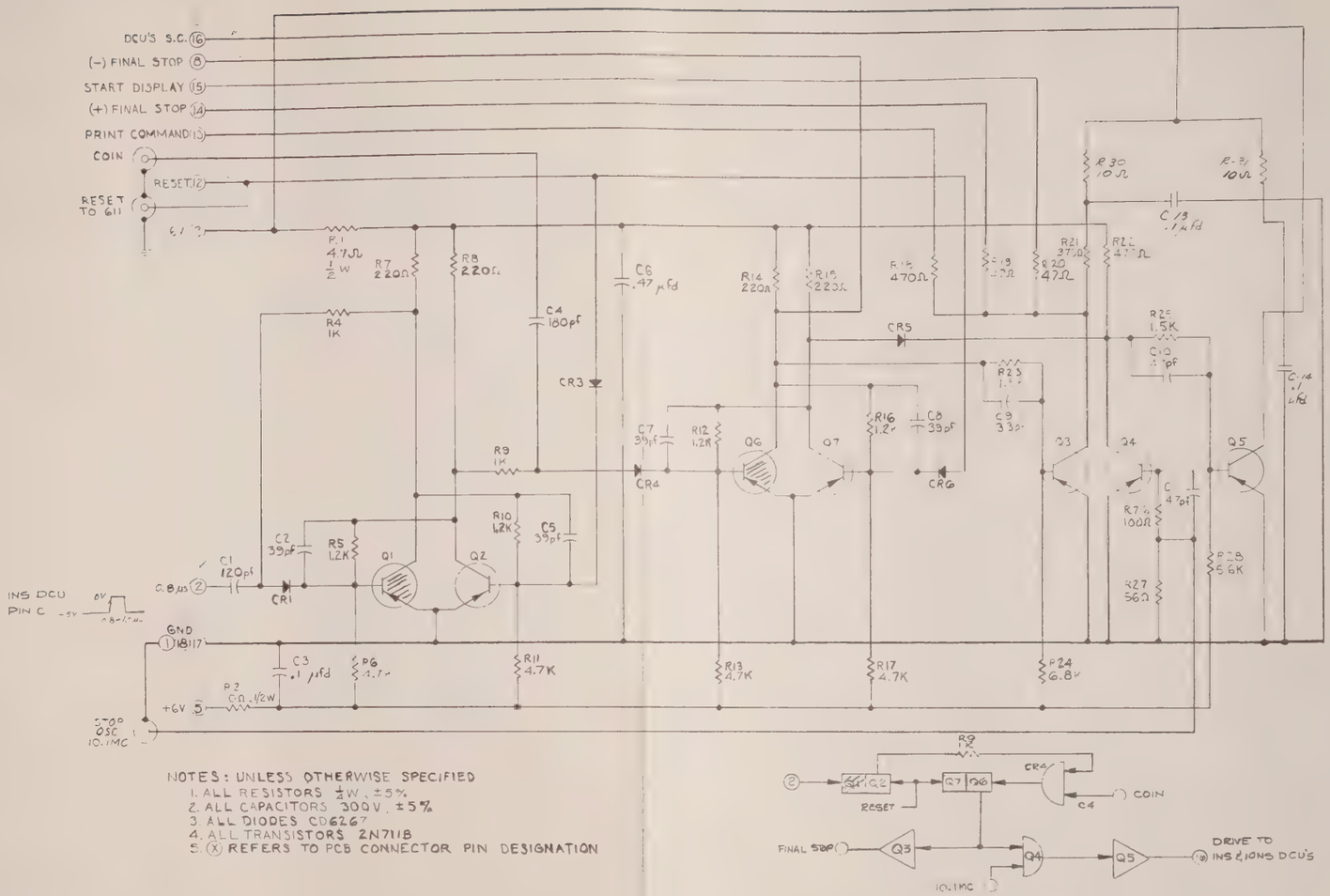
NOTE : UNLESS OTHERWISE SPECIFIED
1. ALL RESISTOR VALUES IN OHMS, ±5%, ¼W
2. ALL CAPACITOR VALUES IN MICROFARADS, ±5%, 300V.
3.
4.

5 (X) REFERS TO PCB CONNECTOR PIN DESIGNATION
6 NOMINAL 27Ω, FINAL VALUE DETERMINED PER AVALANCHE CHARACTERISTICS R20 & R21 MUST BE THE SAME VALUE (TO OBTAIN 6 TO 13 VOLTS OUTPUT INTO 50Ω.)

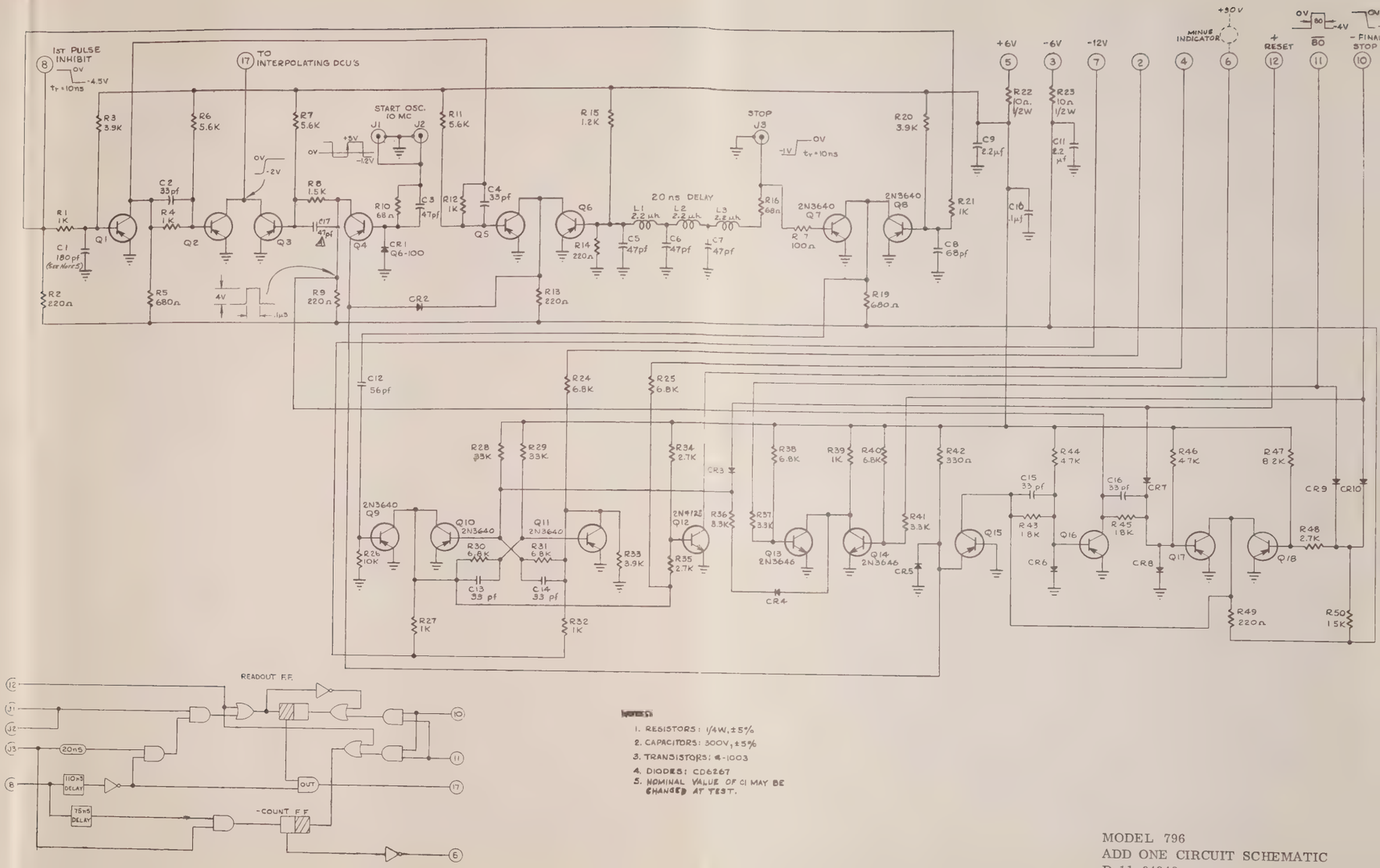
MODEL 796
TEST PULSER SCHEMATIC
C-11-04942



MODEL 796
COINCIDENCE CIRCUIT SCHEMATIC
B-11-04803



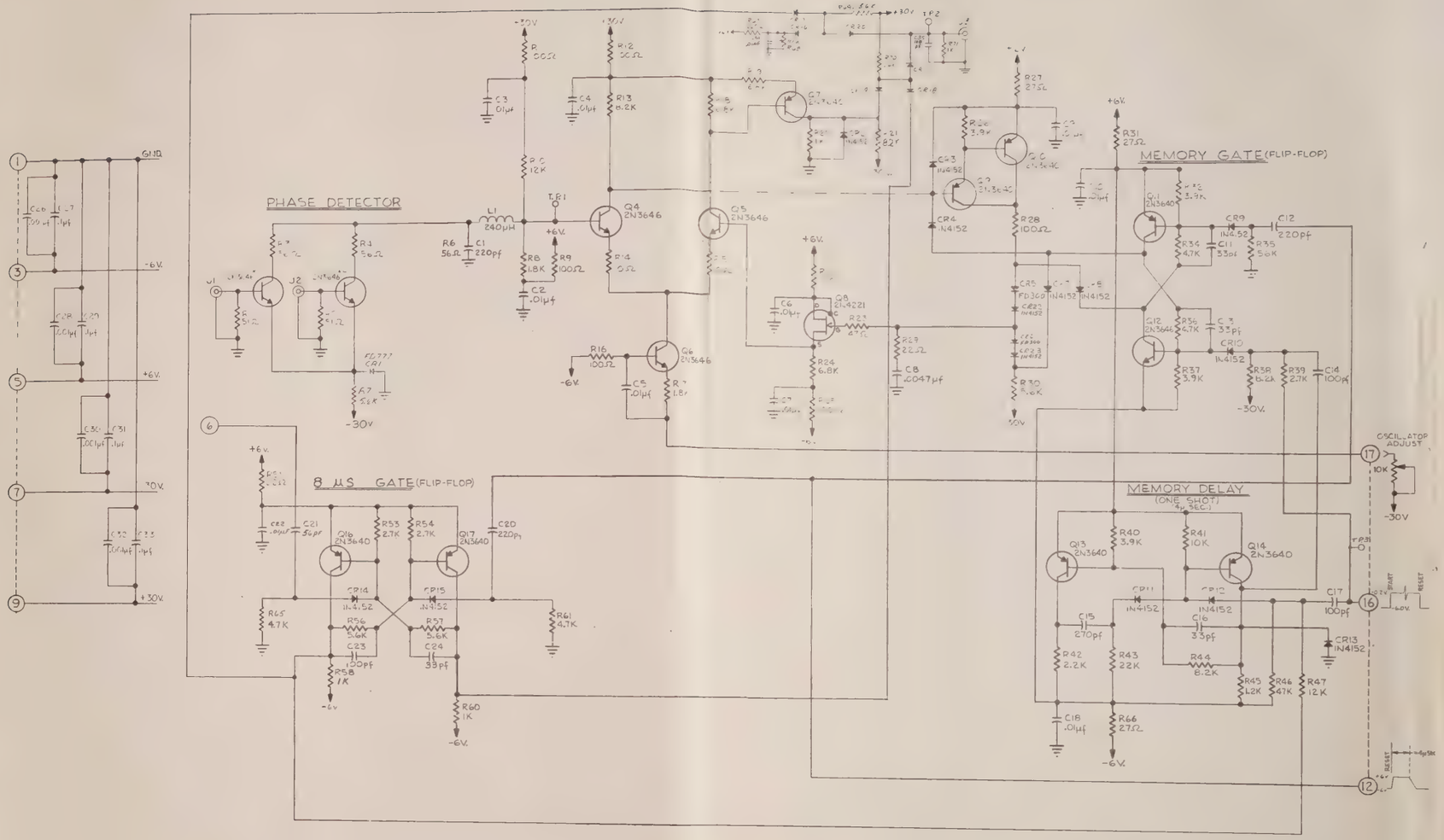
MODEL 796
STOP CIRCUIT SCHEMATIC
C-11-04943



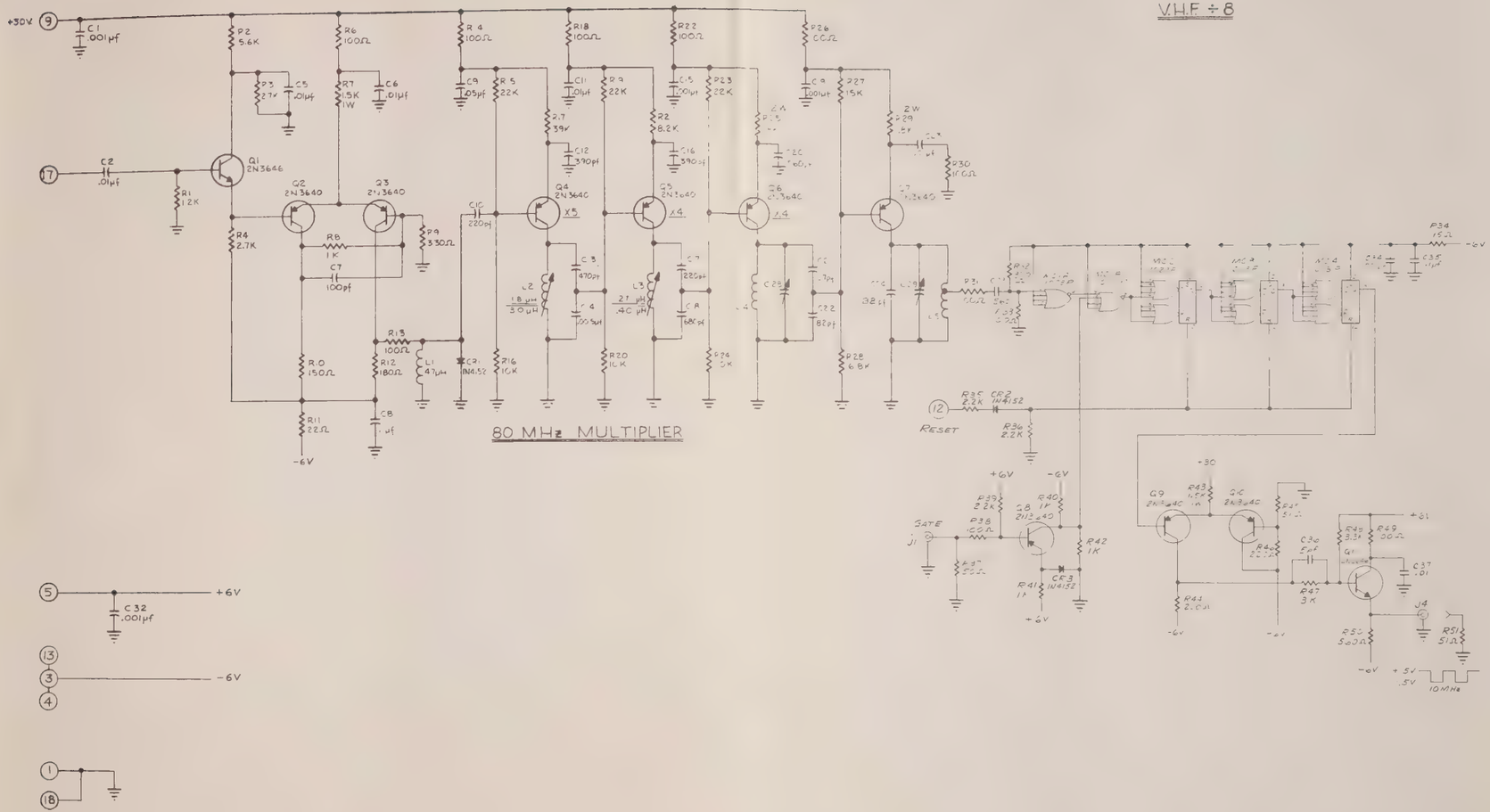
NOTES:

1. RESISTORS: 1/4W, ±5%
2. CAPACITORS: 300V, ±5%
3. TRANSISTORS: ∝-1003
4. DIODES: CD6267
5. NOMINAL VALUE OF C1 MAY BE CHANGED AT TEST.

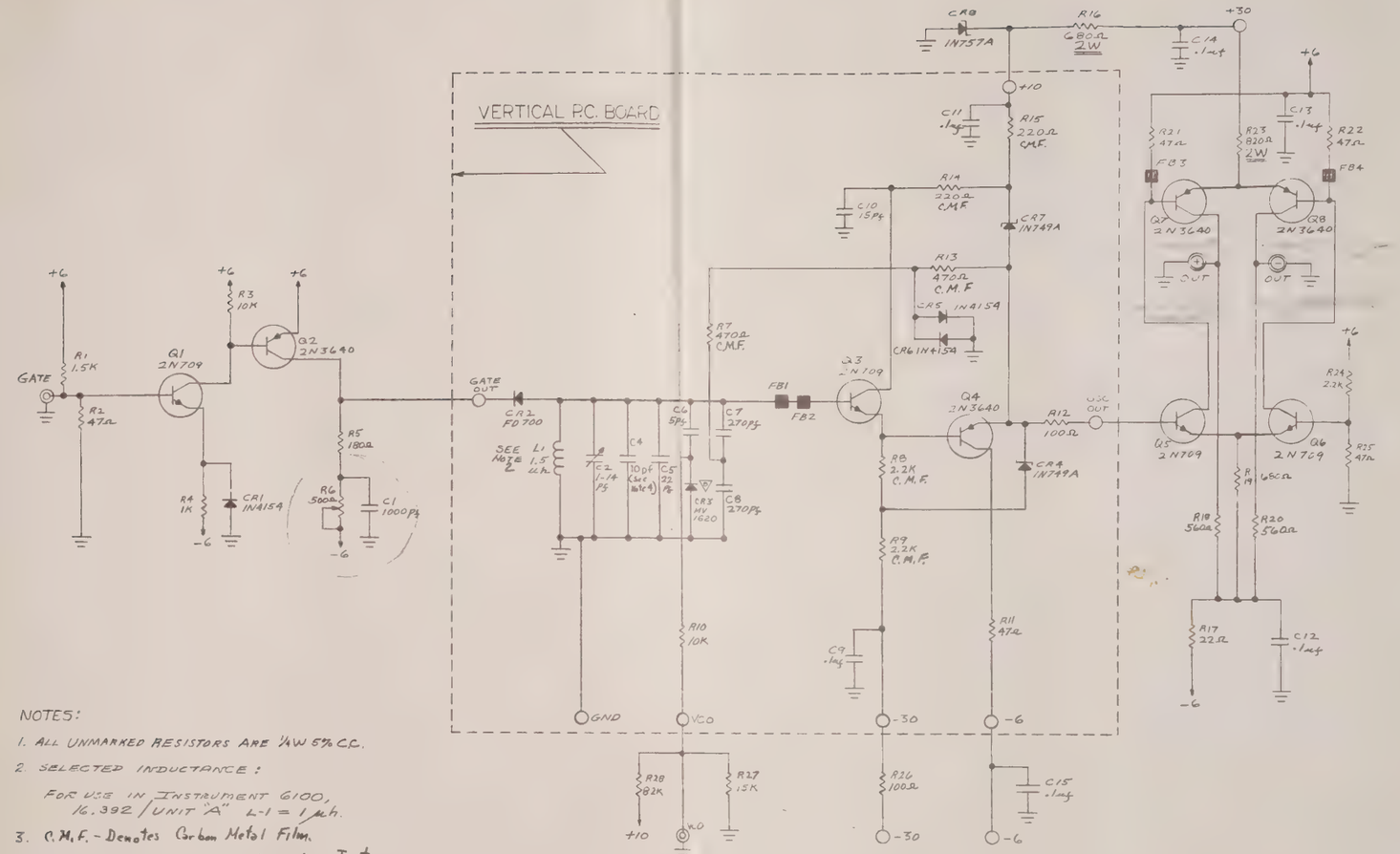
MODEL 796
ADD ONE CIRCUIT SCHEMATIC
D-11-04948



MODEL 796
STABILIZER CIRCUIT SCHEMATIC
D-11-05011



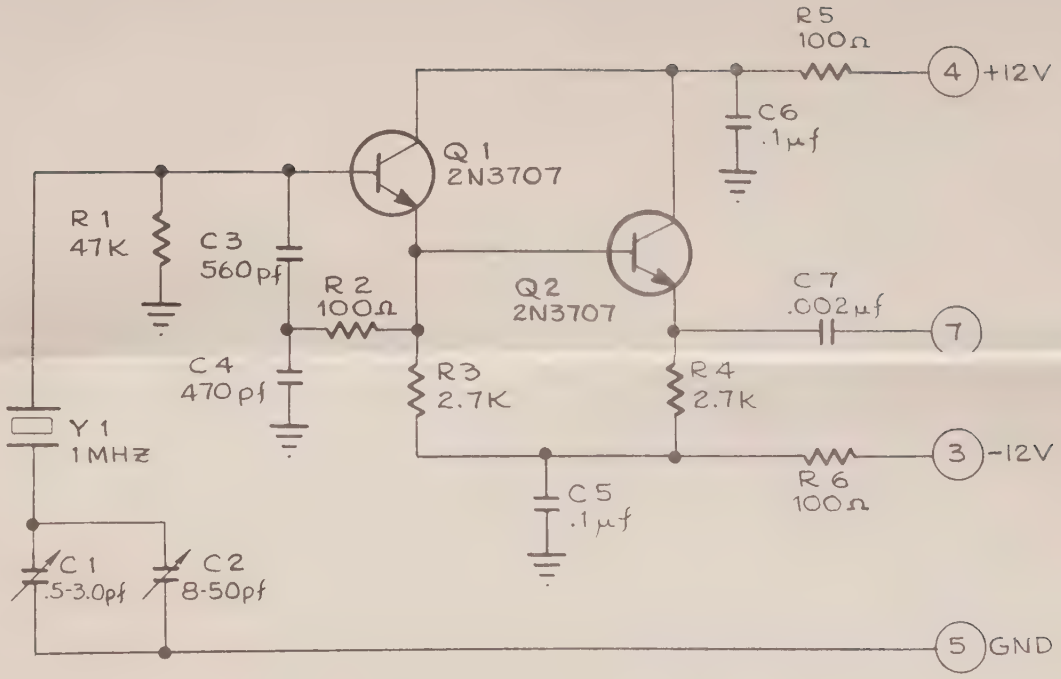
MODEL 796/650
VHF and DIVIDE-BY-EIGHT SCHEMATIC
D-11-05211



NOTES:

1. ALL UNMARKED RESISTORS ARE ¼W 5% C.C.
2. SELECTED INDUCTANCE:
   FOR USE IN INSTRUMENT 6100, 16.392 / UNIT "A" L-1 = 1 μh.
3. C.M.F. - Denotes Carbon Metal Film.
4. Nominal Value - May be changed in Test

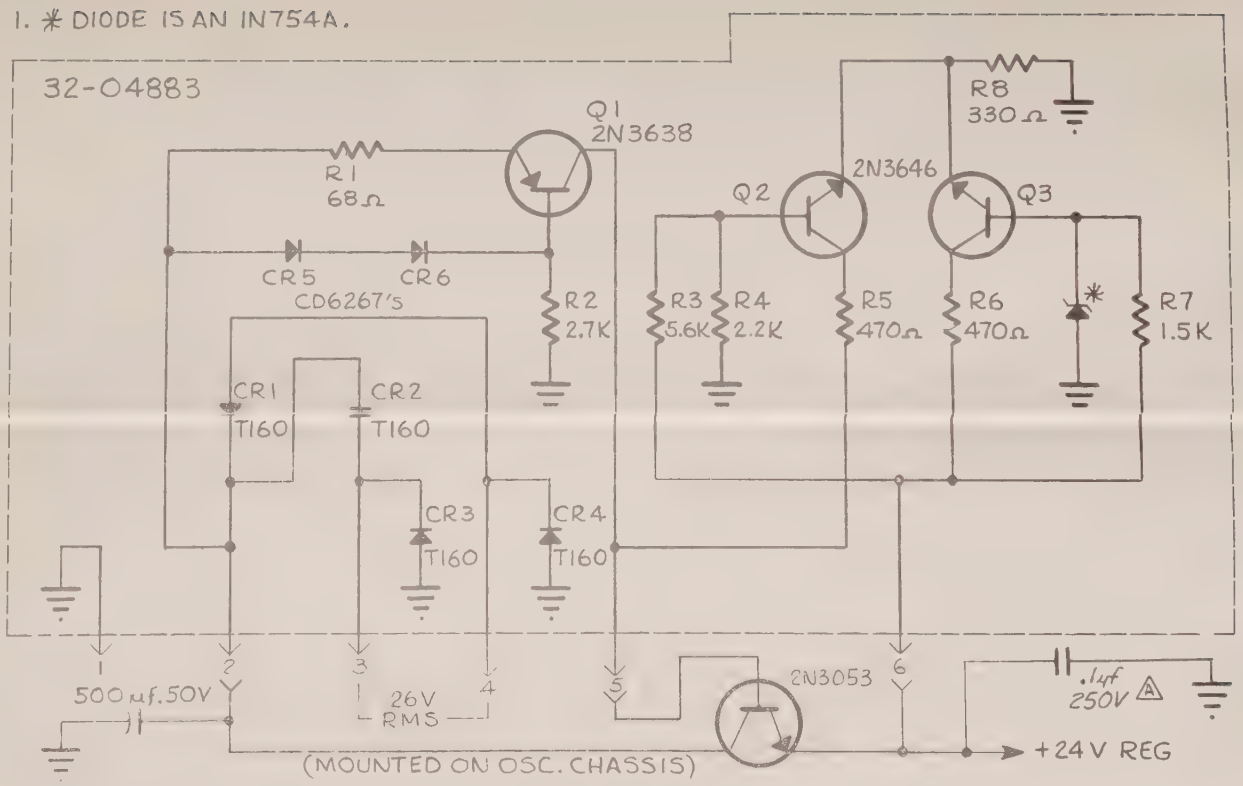
MODEL 796/650
START UP OSCILLATOR SCHEMATIC
C-11-3440



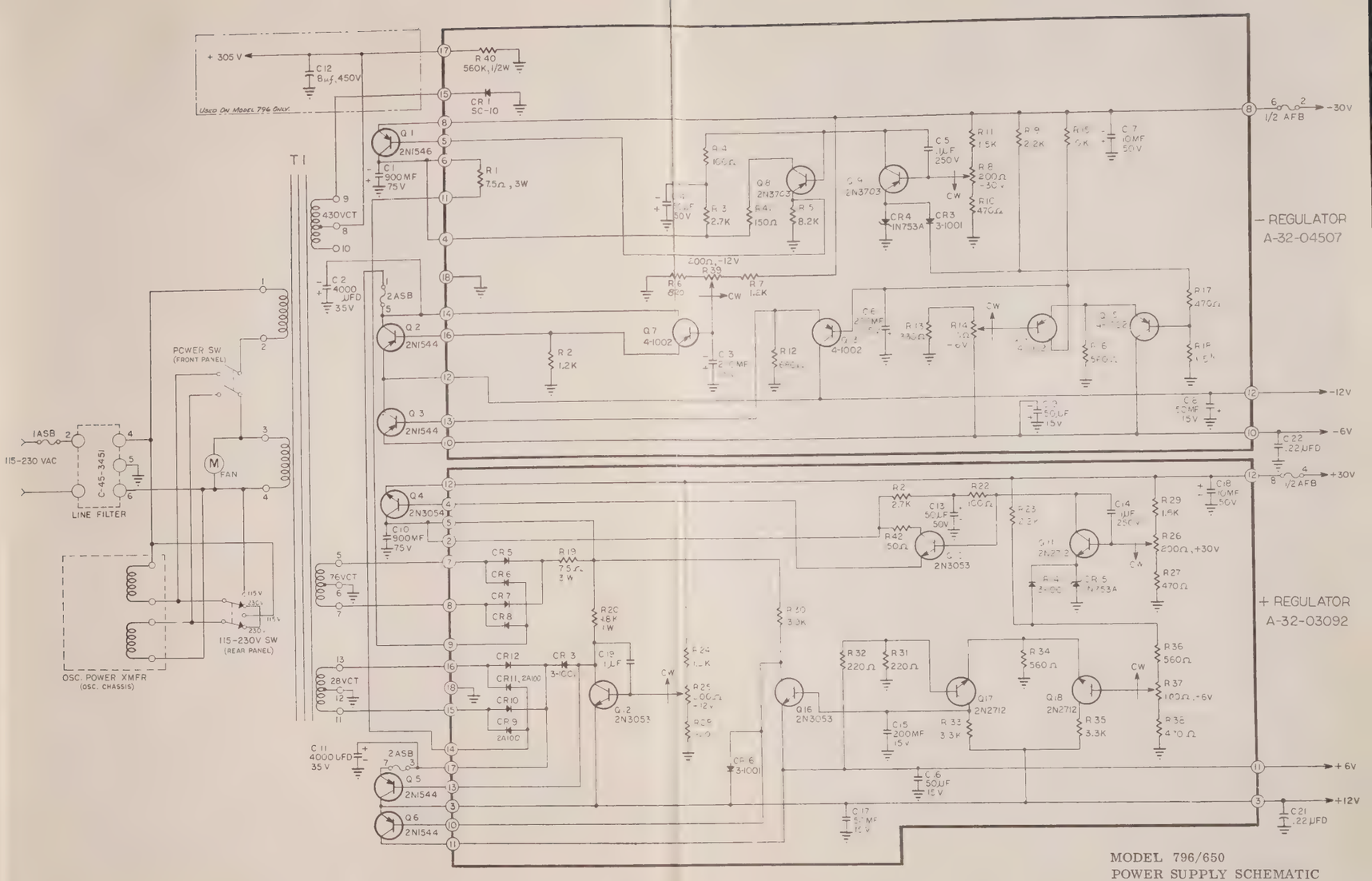
MODEL 796
REFERENCE OSCILLATOR SCHEMATIC
A-11-4979

NOTES:

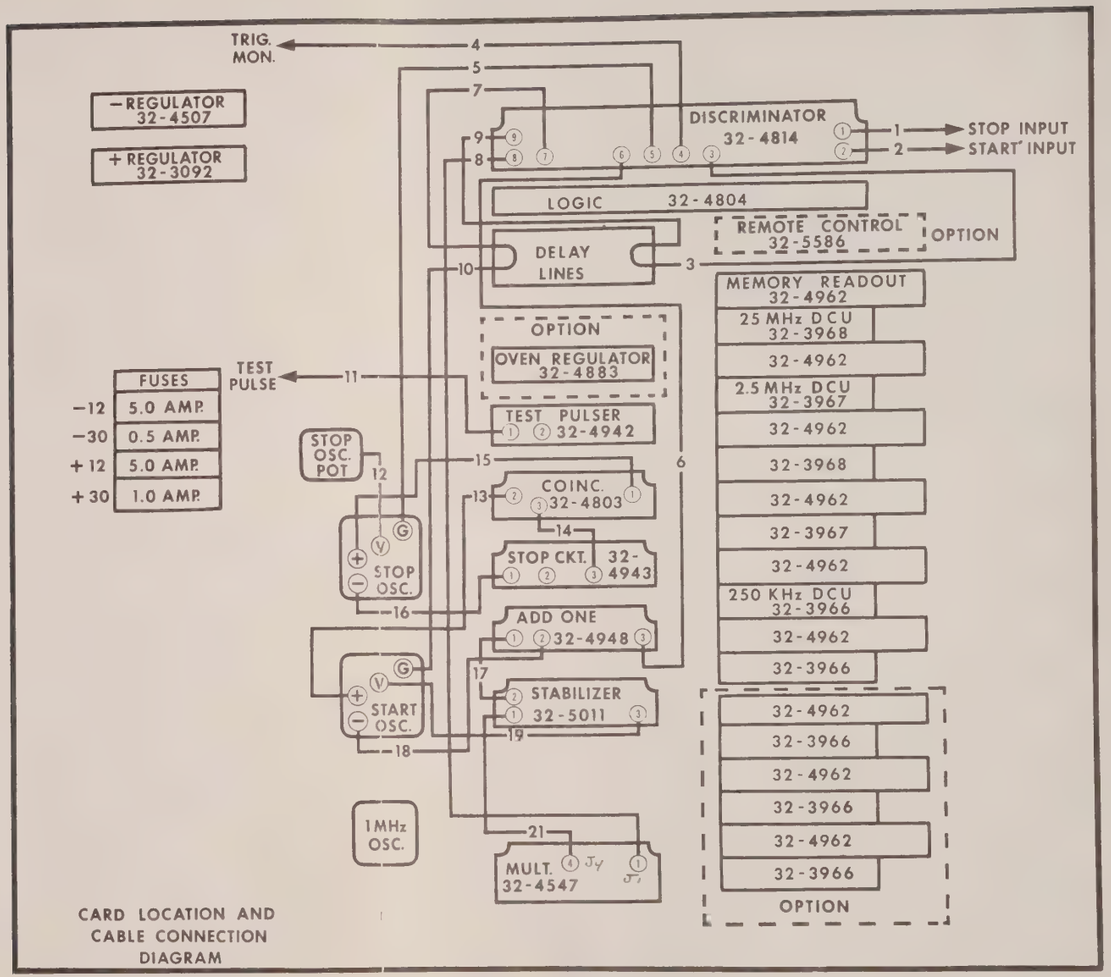
1. * DIODE IS AN IN754A.



MODEL 796/650
OPTION D & E OVEN SCHEMATIC
A-11-04949



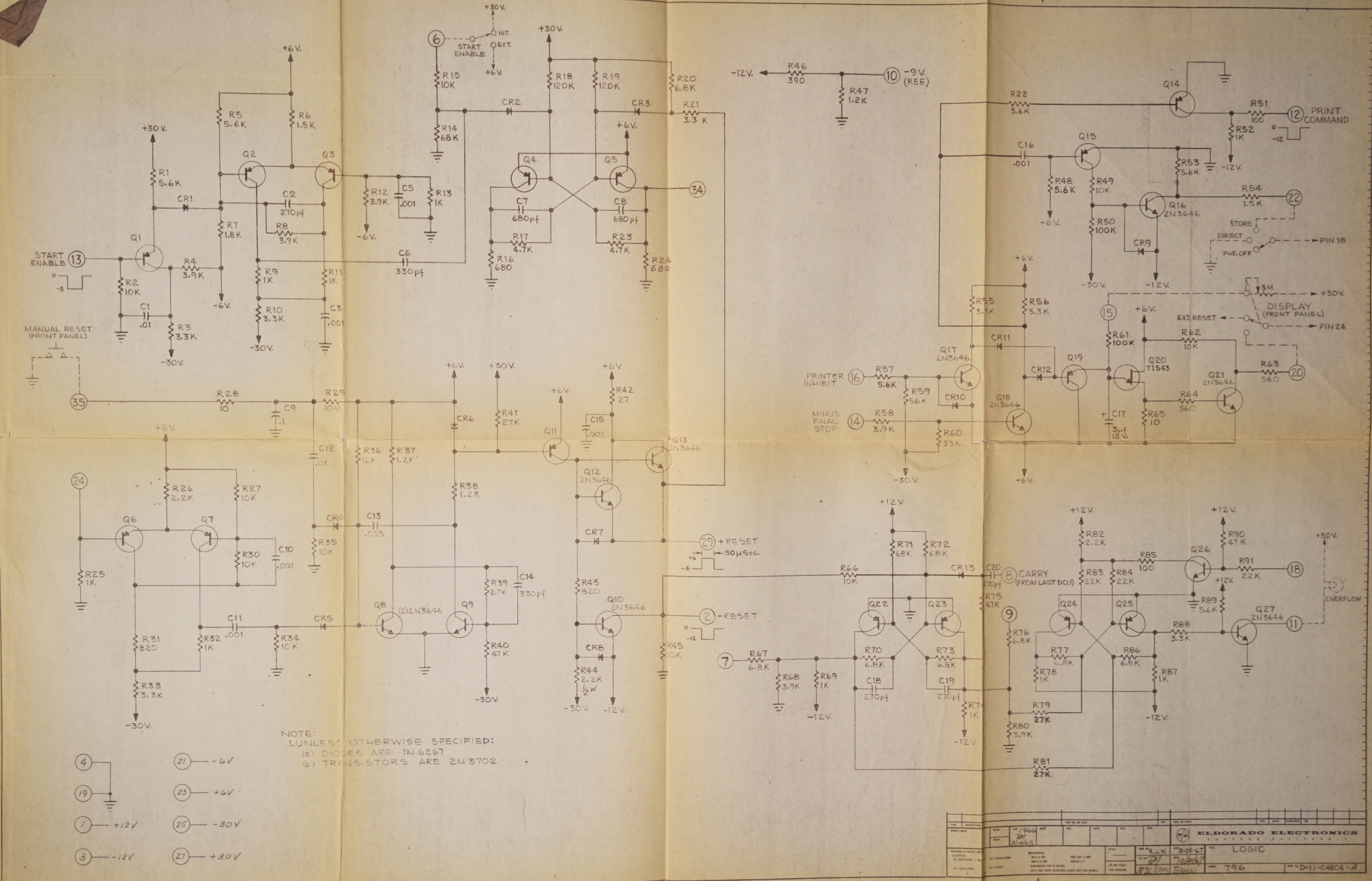
MODEL 796/650
POWER SUPPLY SCHEMATIC
D-11-04917



MODEL 796
PCB LAYOUT
M-25-04905

TABLE 7-1
MODEL 796 TIME INTERVAL COUNTER
ABOVE CHASSIS CABLE LIST

CABLE NO.	FUNCTION	FROM	TO
1	Stop Input	Input B Multiplier	Disc. J1
2	Start Input	Input A Multiplier	Disc. J2
3	Stop Delay	Disc. J3	Delay Box
4	Trigger Monitor	Disc. J4	TRIG MON Connector (rear panel)
5	Stop Oscillator	Disc. J5	Stop Oscillator Gate
6	Stop	Disc. J6	Add One J3
7	Start	Disc. J7	Delay Box
8	Multiplier Gate (start	Disc. J8	Mult. J1
9	Stop Delay (cont. cable 3)	Delay Box	Disc. J9
10	Start (cont. cable 7)	Delay Box	Start Osc. Gate
11	Test Pulse	Test Pulser J1	Test Pulse Connector
12	Stop Osc. Adjust	Stop Osc. Pot (under chassis)	Stop Osc. VCO Input
13	Start Osc. + Output	Start Osc. + Output	Coincidence J2
14	Coincidence	Coincidence J3	Stop Logic J3
15	Stop Osc. + Output	Stop Osc. + Output	Coincidence J1
16	Stop Osc. - Output	Stop Osc. - Output	Stop Logic J1
17	Start Osc. to Stab.	Add One J1	Stabilizer J2
18	Start Osc. - Output	Start Osc. - Output	Add One J2
19	Start Osc. Control	Stabilizer J3	Start Osc. VCO Input
20	Obsolete Cable - - no longer exists		
21	Multiplier Output	Multiplier J4	Stabilizer J1


+30V.
INT.
EXT.
START ENABLE
+6V.
R15 10K
R18 120K
R19 120K
R20 6.8K
CR2
CR3
R21 3.3 K
R14 68K
Q4
Q5
34
C7 680pf
C8 680pf
R17 4.7K
R23 4.7K
R16 680
R24 680
-12V.
R46 390
R47 1.2K
10
-9V. (REF)
Q14
R22 5.6K
R51 100
12
PRINT COMMAND
R52 1K
-12
Q15
C16 .001
R53 5.6K
R48 5.6K
R49 10K
R54 1.5K
22
Q16 2N3646
R50 100K
STORE
DIRECT
PWR. OFF
PIN 18
CR9
-30V.
5M
DISPLAY (FRONT PANEL)
EXT. RESET
PIN 24
R55 3.3K
R56 3.3K
15
R61 100K
R62 10K
CR11
Q17 2N3646
Q19
CR12
Q20 T1543
Q21 2N3646
R63 560
20
PRINTER INHIBIT
16
R57 5.6K
R59 56K
CR10
R64 560
MINUS FINAL STOP
14
R58 3.9K
Q18 2N3646
R60 33K
C17 3µf 12V.
R65 10
Q1
START ENABLE
13
R1 5.6K
R2 10K
R3 3.3K
R4 3.9K
C1 .01
CR1
R5 5.6K
R6 1.5K
Q2
Q3
C2 270pf
R7 1.8K
R8 3.9K
R9 1K
R10 3.3K
R11 1K
C3 .001
R12 3.9K
C5 .001
R13 1K
C6 330pf
MANUAL RESET (FRONT PANEL)
35
R28 10
C9 .1
R29 10M
C12 .01
CR6
R41 27K
R42 27
C15 .001
Q11
Q13 2N3646
Q12 2N3646
R36 12K
R37 1.2K
R38 1.2K
24
R26 2.2K
R27 10K
Q6
Q7
R25 1K
R30 10K
C10 .001
CR4
C13 .005
R35 10K
R39 2.7K
C14 330pf
Q8 (2)2N3646
Q9
C11 .001
CR5
R31 820
R32 1K
R34 10K
R33 3.3K
R40 47K
R43 820
Q10 2N3646
CR7
CR8
R44 2.2K 1/2W
R45 10K
29
+RESET
50µSec.
2
-RESET
+12V.
R71 68K
R72 68K
R66 10K
CR13
C20 270pf
8
CARRY (FROM LAST DCU)
R75 47K
7
R67 6.8K
R68 3.9K
R69 1K
Q22
Q23
R70 6.8K
R73 6.8K
C18 270pf
C19 270pf
R74 1K
R82 2.2K
R90 47K
R85 100
Q26
R83 22K
R84 22K
R91 22K
18
R89 5.6K
OVERFLOW
9
Q24
Q25
Q27 2N3646
11
R76 6.8K
R77 6.8K
R86 6.8K
R88 3.3K
R78 1K
R87 1K
R79 27K
R80 3.9K
R81 27K
NOTE:
1. UNLESS OTHERWISE SPECIFIED:
(a) DIODES ARE 1N6267
(b) TRANSISTORS ARE 2N3702
4
19
1 +12V
3 -12V
21 -6V
23 +6V
25 -30V
27 +30V
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